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WASHINGTON, D. C., METROPOLITAN AREA AIR POLLUTION ABATEMENT ACTIVITY

National Center for Air Pollution Control
Cincinnati, Ohio

November 1967

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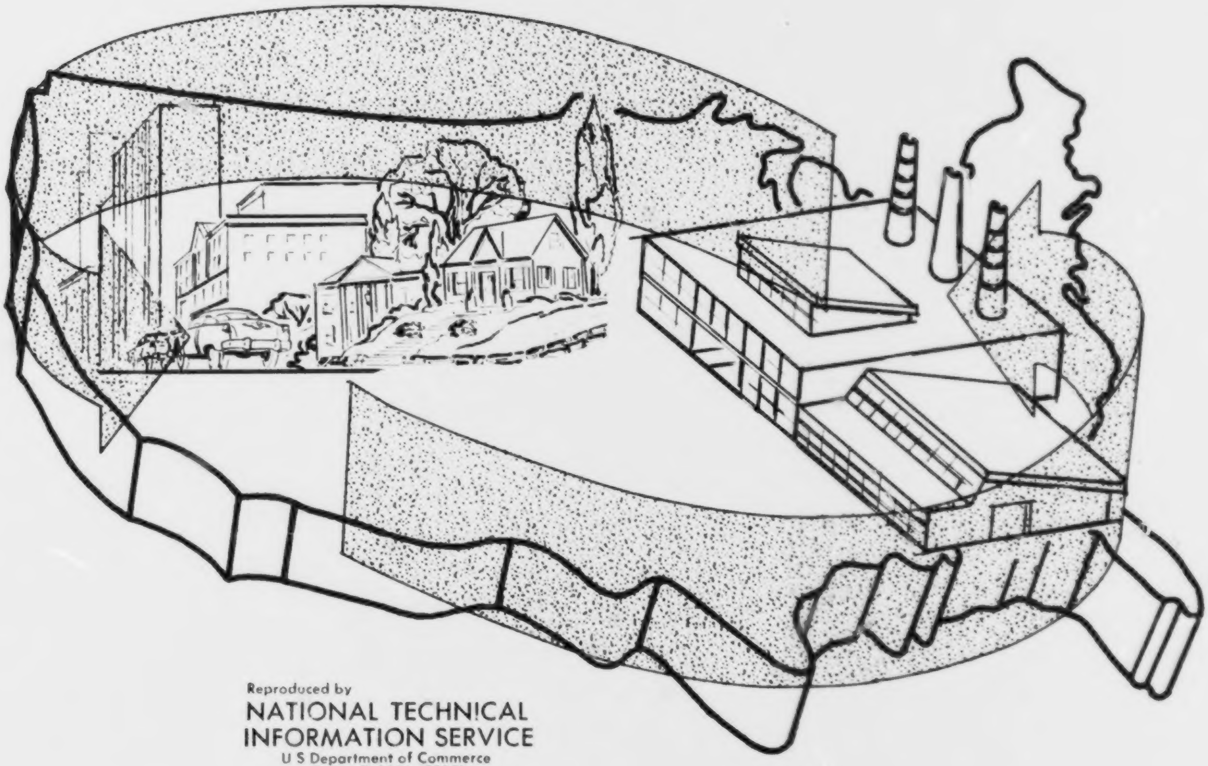

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U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE

Public Health Service
NOVEMBER 1967

215

TECHNICAL REPORT

WASHINGTON, D.C., METROPOLITAN AREA AIR POLLUTION ABATEMENT ACTIVITY

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
National Center for Air Pollution Control
Cincinnati, Ohio
First Printing
1967

WASHINGTON, D.C., METROPOLITAN AREA
AIR POLLUTION ABATEMENT ACTIVITY

ERRATA SHEET

Page 12 - last paragraph, line three: "southwest" should be "southeast".

Page 15 - last paragraph, line one: "expentancy" should be "expectancy".

Page 16 - Table 2, heading: 300 is omitted following "below".
- third paragraph, line four: "an hour before sunrise" should be "an hour before sunset".

Page 18 - last paragraph, line one: "Woolum" should be "Woollum".

Page 19 - last paragraph, line three: "des" should be "does".

Page 30 - Table 12, the one percentile value for the Hyattsville station: "0.01" should be 0.10".

Page 41 - Table 20, all "0" ppm values should be "<1" ppm.

Page 52 - second paragraph, line four: insert "were made" between "measurements" and "of".
- Table 35, % suppression of root system should be "56, 54, 72, 0".

Page 53 - Figure 15, in the legend: "2.1" should be ".21".

Page 73 - Table 41: Maryland Sub-Total is 2, not 3.

Page 74 - Table 41, under the Gasoline Handling and Evaporation column: "14,   " should be "14,316" and "2,   " should be "2,752".
- Table 41 (cont'd): for Alexandria City, insert "19" in third column.

Page 75 - Table 51: Area totals should be "310,139" instead of "310,039" in grand total column.

Page 87 - last paragraph, line two: "bitiminous" should be "bituminous".
- second paragraph, line three: "39" should be "40".

Page 90 - Table 45, omission of footnote b: should be "[b]Negligible sources not included."

Page 93 - Table 46, second value in SO_x column: "62.7" should be "26.7".
- first paragraph, line two: "99" should be"98".
  line six: "44" should be "45".

Page 94 - last paragraph, line five: "bitiminous" should be "bituminous".

Page 95 - Table 48, omissions in SO_x max. column: last four values should be "-", "neg", "-", and "3" respectively.

Page 124 - Table 52: Insert "Fuel" above "Rate" in column three.

Page 127 - first paragraph, line two: "Uning" should be "Using".

Page 148 - first paragraph, last line: "Fatique" should be "Fatigue".
- second paragraph, line two: "Altertness" should be "Alertness".

Page A-10 - Applications, number 1, line two: last word should be "and".
- Applications, number 3, line four: last word should be "population".

Page B-6 - Under Analyzer, line two should be "NO_2".

Page C-3 - fifth paragraph, line one: "fiesel" should be "diesel".

Page C-5 - fifth paragraph, line five: "residential" should be "residual".

This report is based upon an investigation of air pollution conducted in the Washington, D.C., metropolitan area in the period of February, 1967 to August, 1967. The report is intended to assist the governmental agencies concerned with such air pollution in their consideration of the following:

1. Occurrence of air pollution subject to abatement.
2. Adequacy of measures taken toward abatement of pollution.
3. Nature of delay, if any, in abating the pollution.
4. Necessary remedial action, if any.

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WASHINGTON, D.C., METROPOLITAN AREA AIR POLLUTION ABATEMENT ACTIVITY

I. INTRODUCTION

From February 1967 to August 1967 the Public Health Service of the Department of Health, Education, and Welfare conducted a technical investigation in the Washington, D. C., metropolitan area to provide information that could form a basis for a public conference under Subsection 105 (c)(1)(C) of the Clean Air Act, as amended (42 U.S.C. 1857, et seq.). With the information brought forth at the conference, the Secretary of Health, Education, and Welfare may thereupon make recommendations for abatement in accordance with the tenets of the Clean Air Act.

The following agencies agreed to participate in the investigation with technical support: The District of Columbia Department of Health, Maryland Department of Health, Virginia State Air Pollution Control Board, Metropolitan Washington Council of Governments, and a number of local and Federal agencies in the District of Columbia, Maryland, and Virginia.

Several air pollution surveys and hearings have been conducted in this area over the past several years. The most pertinent of these are summarized, and their results are utilized wherever applicable.

This report presents the results of the 1967 investigation and describes the methods, techniques, and procedures followed. In concert with cooperative regional and local agencies, an air quality network was established, an emissions inventory was conducted, extensive meteorological data were acquired, air pollution effects on vegetation and various materials were investigated, and special data processing and summarization techniques were developed.

This report is to be forwarded to all cooperating agencies prior to the aforementioned conference. The evaluation and correlation of results presented in this report reflect the scientific and technical judgement of the personnel of the National Center for Air Pollution Control, Public Health Service, U. S. Department of Health, Education, and Welfare.

HISTORY OF ABATEMENT ACTION AND PAST STUDIES

For many years interstate air pollution has reflected condition detrimental to the environment of the Washington, D. C., metropolitan area. Over the years several studies, investigations, and hearings into medical, engineering, agricultural, economic, esthetic, and other aspects of the problem have been undertaken by governmental agencies at all levels, by universities, and by private concerns. The more pertinent of these surveys, particularly those of a technical nature are summarized in this section.

Washington, D. C. and Rockville, Maryland have participated in the National Air Sampling Network of the Public Health Service. Samples of air are collected bi-weekly for 24-hour periods with high-volume samplers. The 1964-1965 data from these stations and nearly 300 others are presented in a 1966 Public Health Service publication.[1] This data is summarized later in a section on air quality.

In the January 23, 1959, issue of Science Magazine, Heggestad and Middleton reported extensive damage to tobacco from ozone at Beltsville, Maryland.[2]

During June 1959, the metropolitan area experienced a 4-day episode of eye-irritating photochemical smog of the type first described in Los Angeles. Because of this incident and other concern about the air pollution problem, an Automobile

Nuisance Abatement Committee was formed in May 1960. This committee was established to promote control of unnecessary noise, smoke, and fumes from automotive equipment operated within the Washington metropolitan area. As a result of several committee meetings and other activities, the District of Columbia Fuel Burning Equipment Regulations and the Traffic and Motor Vehicle Regulations were amended to require reduction of certain air pollution emissions.[3]

In the past several years, the Washington area has experienced photochemical smog on a number of occasions at levels that cause reduced visibility, eye irritation, and damage to vegetation. To define this problem better, the Metropolitan Washington Council of Governments, which is composed of all local governments in the region, in cooperation with State and Federal agencies, initiated an oxidant sampling network in October 1961. The network is continuing to operate and the results are summarized in a following section on air quality.

The Automotive Nuisance Abatement Committee was superseded by the Regional Air Pollution Advisory Board of the Metropolitan Washington Council of Governments. The Advisory Board is composed of local, state and Federal government officials who are concerned with air pollution control activities. The Board, through the Council of Governments, advises the local elected officials in the metropolitan area of air pollution problems and proposes corrective measures. The Metropolitan Washington Council of Governments, as a voluntary organization of local governments in the area, promotes cooperative programs such as the oxidant sampling network and area-wide air pollution control measures.[3]

In 1962 a Continuous Air Monitoring Program (CAMP) station was established in downtown Washington by the Public Health Service to measure carbon monoxide, sulfur dioxide, nitric oxide, nitrogen dioxide, ozone, total oxidants, and total hydrocarbons. The station is equipped to make certain other measurements. The station is continuing in operation and provides much valuable data about specific air pollutants. The data from the CAMP station were incorporated with the results of this study and summarized in the section on air quality.

In July 1962 the Public Health Service released a report entitled "Air Pollution in the National Capital Area".[4] The report stated that the Washington, D. C., area was polluted and that air pollution in the area may be expected to increase rapidly, unless adequate control measures are taken. The report went on to recommend the following: A comprehensive air pollution control program including laboratory support should be established. A metropolitan air pollution advisory board should be organized to coordinate the total air pollution effort in the metropolitan area.

In 1962, Fairfax County, Virginia, adopted an air pollution control ordinance, one of the first in the Washington, D. C. area.

In October of 1965 Montgomery County, Maryland adopted an extensive air pollution control ordinance.

On July 14, 1966, the Board of Directors of the Metropolitan Washington Council of Governments (COG) adopted a Model Air Pollution Control Ordinance that could be used by local governments in developing control ordinances for their communities. A provision in the Model Ordinance limits the sulfur content of fuels to 1 percent by weight. This ordinance was adopted by Montgomery County, Maryland, on July 5, 1967, and by the city of Falls Church, Virginia, on August 20, 1967, to be effective November 1, 1967. Prince Georges County, Maryland, has drafted a proposed air pollution ordinance similar to the COG Ordinance. A public hearing on this ordinance will be held in the near future.

Under a 1966 State law, the newly created Virginia State Air Pollution Control Board appointed an Executive Secretary to that Board on January 1, 1967.

Under a 1967 State law, the Maryland State Health Department has recently submitted proposed air pollution regulations to the newly created Maryland Air Pollution Council for advice on the regulations. The new state air pollution law establishes a Washington metropolitan area for which regulations may be passed that are pertinent to that area with the provision that regulations for that area would have precedence over any less-stringent local regulations.

During the second week in March 1967, joint hearings were held before the subcommittee on Business and Commerce and the subcommittee on Public Health, Education, Welfare, and Safety of the Committee on The District of Columbia, United States Senate on the problems of air pollution in the District of Columbia.[5] The subjects covered by the hearings included air pollution in general, Federal sources, private sources, the Kenilworth dump, control programs in other cities, and control efforts of the District of Columbia.

The above hearings resulted in Senate Bill (S.1941) to prevent, abate, and control air pollution in the District of Columbia. Hearings were held on this bill on July 20 and August 29, 1967. As of this date the bill has not been passed.

In June 1967 the Solid Wastes Program of the Public Health Service prepared for the District of Columbia Committee of the U. S. Senate a report on the District of Columbia incinerator system. The report gave a score of "unsatisfactory" to each of the four incinerators studied.[6]

On July 19 and 20, 1967, the Surgeon General of the United States held a conference on the solid waste problems in the Washington, D. C., metropolitan area. In many ways this was an air pollution conference because it pointed out the air pollution caused in the area by improper disposal of solid wastes.

On August 10 and 16, 1967 hearings were held before Subcommittee No. 2 on the Committee on the District of Columbia House of Representatives on H.R. 6981, H.R.

10017, and H.R. 12232 to provide for the prevention, abatement, and control of air pollution in the District of Columbia. The hearings brought forth the fact that the District of Columbia Department of Public Health has only a coordinating role and little or no authority for air pollution abatement.[7] These bills have not yet been passed.

The record reflects that the Board of Directors of the Metropolitan Washington Council of Governments adopted a multistage alert system for sulfur dioxide, soiling, and oxidant. This system is designed to alert the public to potential pollution episodes.

Until recently, Federal air pollution legislation made no provision for abatement action. On December 17, 1963, however, President Johnson signed the Clean Air Act (Public Law 88-206), which replaces previous Federal legislation in the air pollution field. One of the principal provisions of this Act authorizes the Department of Health, Education, and Welfare to engage directly in abatement activities when the health and welfare of the citizens of one state is endangered by air pollution discharged in another state.

The Clean Air Act, like the Federal air pollution legislation it replaced, recites that the primary responsibility for the regulatory control of air pollution rests with state and local governments. For the first time, however, the Federal government was authorized to take abatement action.

On September 8, 1966, President Johnson directed the Secretary of Health, Education, and Welfare, John W. Gardner, to request officials of the District of Columbia, Maryland, and Virginia to consult with the Department of Health, Education, and Welfare on air pollution in the interstate Washington, D. C., metropolitan area. Representatives of the District of Columbia, the States of Maryland and Virginia, the Metropolitan Washington Council of Governments, and the Department of Health, Education, and Welfare met in consultation in Washington, D. C., on November 23, 1966; Mr. S. Smith Griswold presided as representative of the U. S. Department of Health, Education, and Welfare. At the consultation the agreement was made that an air pollution abatement activity would be initiated without delay and would be coordinated by the Abatement Program, National Center for Air Pollution Control, with full cooperation of the state and local agencies.

In accordance with Subsection 105 (c) (1) (C) of the Clean Air Act, as amended (42 U.S.C. 1857, et seq.), the activity was conducted between February and August, 1967 to gather technical data and information on air pollution in the interstate Washington, D. C., metropolitan area. Overall technical direction, administration, and coordination of the activity were provided by the Abatement Branch through a supervisory staff located at field headquarters in the study area.

DESCRIPTION OF STUDY AREA

The geographic area of the abatement action comprises the 2,045 square-mile, tri-state area shown in Figure 1. This area is widely diverse in population density, land use, industrialization, and economic activities. The boundaries for the activity conformed to the Metropolitan Washington Council of Governments' area-which includes the District of Columbia; the Maryland counties of Montgomery and Prince Georges; the Virginia counties of Arlington, Fairfax, Loudoun, and Prince William; and the independent cities of Alexandria, Falls Church, and Fairfax.

The Washington, D. C., metropolitan area is located at the western edge of the Middle Atlantic Coastal Plain and the eastern edge of the Piedmont Plateau, 35 miles west of the Chesapeake Bay and far enough inland from the ocean to escape the sea breeze effects. The Blue Ridge Mountains, rising to an elevation of 3,000 feet or more, begin at the western edge of the study area. The orographic effect of these mountains warms and drys westerly winds reaching the area.

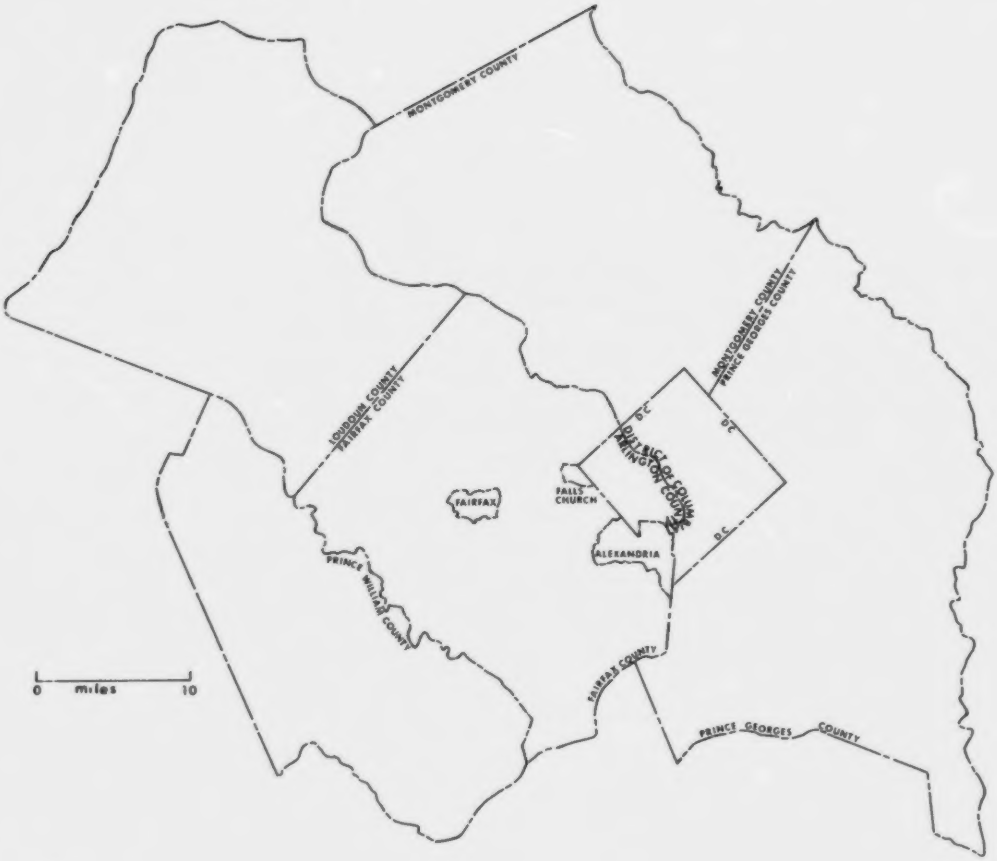

MONTGOMERY COUNTY
LOUDOUN COUNTY
FAIRFAX COUNTY
MONTGOMERY COUNTY
PRINCE GEORGES COUNTY
D.C.
D.C.
DISTRICT OF COLUMBIA
ARLINGTON COUNTY
FALLS CHURCH
FAIRFAX
D.C.
ALEXANDRIA
PRINCE WILLIAM COUNTY
FAIRFAX COUNTY
PRINCE GEORGES COUNTY
0
miles
10

Figure 1. Area included in Metropolitan Washington, D. C., Abatement Activity.

The terrain to the east of the Washington area is generally flat, with elevations of less that 100 feet above sea level. To the west, gently rolling hills, with elevations of 200 to 500 feet above sea level, extend to the Blue Ridge Mountains.

By far the largest single employer in the Washington, D. C., metropolitan area is the Federal government, which employs nearly one-third of the entire labor force of over 1,000,000.[8] The second-highest percentage of the total employment is directed toward providing necessary goods and services. Manufacturing is a minor source of employment, employing only 50,500 persons.[9] The value added by manufacture (VAM) is less than $550 million,[9] as compared to the approximately $3 billion VAM's for the similar size areas of Pittsburgh and St. Louis. Employment in the research and development fields has greatly increased in recent years. Today the greater Washington area ranks first among U. S. metropolitan areas in the number of scientific persons employed per 1,000 of the population; these include scientists in the Government service.

According to the 1965 estimates, more than 2.5 million persons live in the study area.[8] The population density for the entire area is 1,234 persons per square mile. The density ranges from a high of 13,300 in the District of Columbia to a low of 63 in Loudoun County.

About 32 percent of the population lives in the District of Columbia, while most of the remaining population lives in the counties of Prince Georges, Montgomery, Fairfax, and Arlington, and the cities of Fairfax, Falls Church and Alexandria. Prince William and Loudoun counties, although comprising 42 percent of the study area, contain only 4 percent of the area population.

By the year 1980 the population of the study area should reach 3.7 million and by 2000 this figure should reach 5.3 million persons. As would be expected, most of the increased growth will take place outside of the District of Columbia. By the year 2000 the District of Columbia and the counties of Prince Georges, Montgomery, and Fairfax should each have nearly a million or more inhabitants.[8]

Another factor of importance to the air pollution aspects of the study area is the fact that there are 784,640 passenger car registrations[9] in the study area. The passenger car density is the highest in the District of Columbia with 3,300 cars per square mile, or nearly nine times the area average of 384 cars per square mile. Like population, the number of automobiles should more than double by the year 2000.

These brief statistics do not permit a quantitative determination, but they provide some indication of the air pollution potential of the area as a whole and a comparison of the separate areas.

II. CLIMATOLOGY

INTRODUCTION

The atmosphere dilutes and disperses air contaminants. The rate of horizontal dispersion is generally indicated by the speed, direction, and variability of winds sensed near the level at which pollutants are emitted. The rate of vertical dispersion is generally determined by the character of the temperature distribution with height. Other factors, such as urban-rural relationships, topographic and terrain features, cloudiness, sunshine, and sea-land configurations, play a part in the development of conditions that disperse pollutants effectively or poorly, but the major role of these factors is their effect on the wind and stability, both of which control the rate of dispersion.

Air pollution decreases with increasing wind speed. Paradoxically, however, strong winds may result in local incidences of high pollution by causing aerodynamic downwash, which may carry stack effluents quickly to ground level. Nevertheless, area-wide contamination levels consistently decrease as wind speeds increase.

The relationship between wind direction and pollution sources determines the patterns of contamination. Areas of greatest contamination are downwind from major sources in the path of most frequently occurring winds. Wind direction and speed provide an index of the horizontal transport and diffusion of pollutants.

The rate of vertical mixing of pollution is implied by the temperature change with height. When the temperature decreases rapidly with increasing height, the unstable air causes rapid and thorough mixing of the contamination and concentrations are quickly reduced. When, on the other hand, the temperature decreases slowly or increases (inversion) with increasing height, the air is stable. The volume of the air available for diluting the pollutants and the vertical mixing rate is severely reduced. The effect of the stable air on ground-level pollution concentrations depends on whether the stable layer is at the surface or aloft. If the stable layer is based at the ground, pollutants tend to remain near the level at which they are emitted and to diverge slowly and horizontally. If the stable layer is aloft, pollutants emitted below it tend to rise and accumulate at its base. When the heat from a rising sun warms the air beneath the elevated stable layer and accumulated pollution sufficiently to cause convection processes to occur, a "fumigation" occurs. The pollutants accumulated aloft are mixed quickly and transported to ground level, where high concentrations may prevail for an hour or more. These events usually occur shortly after sunrise when the inversion dissipates.

Prolonged periods of pollution can develop when high-pressure systems stagnate over an area. The light winds, elevated inversions, and nighttime ground-based inversions associated with slow-moving or essentially stationary systems severely inhibit both the vertical and horizontal mixing of pollution. High pollution concentrations develop and often remain in the area for extended periods of time.

TOPOGRAPHY

Metropolitan Washington is situated at the western edge of the Atlantic Coastal Plain, 35 miles west of Chesapeake Bay. The Blue Ridge Mountains rise to 3,000 feet about 50 miles to the west and affect Washington's weather by markedly warming and drying winds from the west. The coastal plain to the east is essentially flat. Although no topographic barrier exists between the area and Chesapeake Bay and the Atlantic Ocean, the city is too far inland to be affected by the summer sea breezes[4].

The terrain of the city itself varies from sea level to slightly over 400 feet. Bluffs along the Potomac River and Rock Creek, and to the southeast and east of the Anacostia River suggests some channeling of the airflow, but, generally, the terrain does not seriously impede the free movement of air about the city.

WINDS

Surface winds as measured at the National Airport, which has an excellent exposure near the center of the metropolitan area, are most frequently from the northwest during the colder months and south and southwest during the warmer months. Wind roses for each season and the year are shown in Figures 2 and 3.

Wind directions slightly above the surface are more indicative of the direction of transport of contaminants. Wind data from the 300-foot level of a tower at Silver Hill, Maryland, in the southwest portion of the area, and a tower at Tyson's Corner, Virginia, in the western portion of the area, were summarized for January, April, July, and October 1966, and for as much of the study period, January through July 1967, as the towers were operated by the U.S. Weather Bureau.

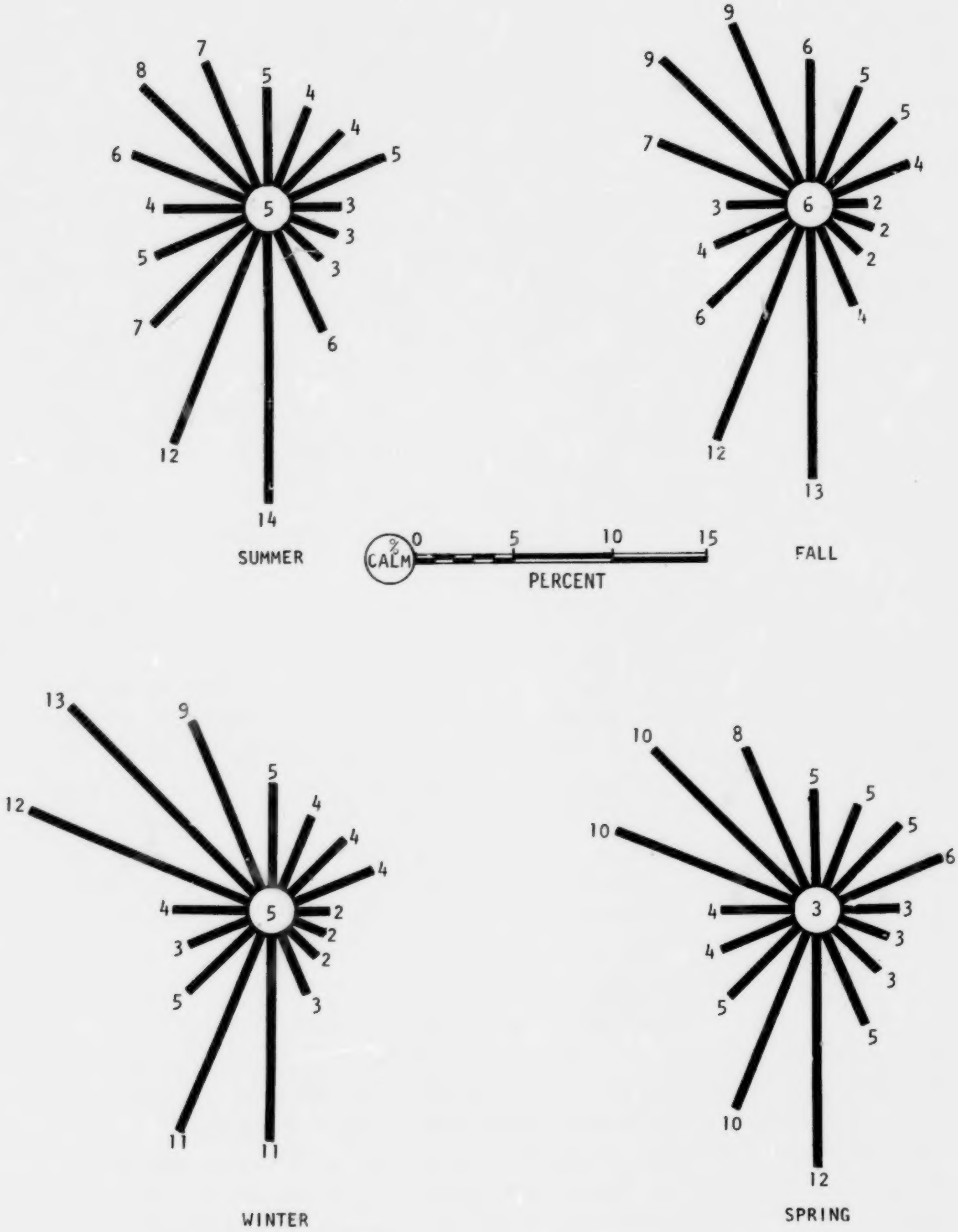
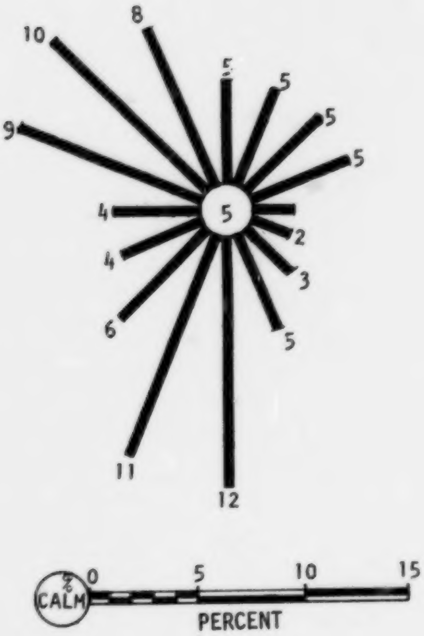


Figure 2. Seasonal percent frequency of occurrence of wind direction from 1951 through 1960 at Washington National Airport.

Figure 3. Annual percent frequency of occurrence of wind direction from 1951 through 1960 at Washington National Airport.[10]



Wind roses for January through April 1967 for the 300-foot level of the towers were compared with those for National Airport. At 300 feet, the most frequent wind directions are about one compass point clockwise from the most frequent directions at the airport. This finding is more pronounced when flow is southerly than when it is northerly. The observation is consistent with meteorological theory since northerly winds during the winter and spring are markedly stronger than southerly winds. Turbulence tends to be greater with northerly winds; and through 300 feet at least, the rate of turning with height in northerly flow would be expected to be less than in southerly flow.

Winds at 300 feet, a level at which many pollutants travel, are considerably stronger than at the surface. Monthly mean speeds sensed for 8 months of 1966 and 1967 at the 300-foot level of the Silver Hill and Tyson's Corner towers were compared with wind speeds at the National Airport. The 300-foot mean speed for the 8 months sampled was 28 percent greater than the mean speed of the airport ground-level winds. In summer, the 300-foot wind speed is about 12 percent greater than ground-level wind speed. During the other seasons mean wind speed at the 300-foot height is slightly more than 30 percent greater than that at ground level.

STAGNATIONS

During periods of stagnating anticyclones many weather factors conducive to developing high pollution concentrations occur simultaneously. Korshover notes that Washington was affected by 48 stagnating anticyclone situations for a total of 231 days during the 30-year period from 1936 through 1965.[11] The average duration of each situation is 4.8 days. In 3 of the 48 cases, the stagnations persisted for 7 days or more. The months of August, September, and October are most susceptible; 34 of the 48 events occurred during these months. No stagnations have been recorded during January through April. To recapitulate, a stagnation is to be expected at least once during the period from August through October, and another, every other year during the months May through December.

STABILITY

The rate that pollutants disperse in the vertical is largely a function of the stability of the air into which they are emitted. As pointed out earlier, contaminants may also accumulate aloft under an elevated inversion.

Hosler estimated the frequency of occurrence in the Washington area of inversions below 500 feet[12,13]. His work was based on radiosonde data accumulated at Silver Hill in the period from 1957 to 1960. The site was considered to be semi-urban. When the radiosonde site was moved to Sterling, Virginia, a rural area, he repeated his earlier study during 1960, 1961, and 1962. A comparison of the inversion frequencies is shown in Table 1.

Table 1. PERCENT OF TOTAL HOURS OF INVERSIONS BELOW 500 FEET IN WASHINGTON, D.C. (PERCENT) AREA FROM RADIOSONDE DATA[12]

	Winter	Spring	Summer	Fall
Silver Hill	37	26	25	36
Sterling, Va.	40	29	31	43

The data in Table 1 indicate a greater expentancy of inversions occurring at the Sterling site, which is considerably more distant from the urban center than is Silver Hill and also that inversions are more frequent in fall and winter than in spring and summer.

The U.S. Weather Bureau instrumented 300-foot towers at Silver Hill and Tyson's Corner. Temperatures were sensed at the surface and at 100-, 200-, and 300-foot levels. Temperature differences between the surface and 300 feet were calculated each hour for the months of January, April, July, and October of 1966; for January through April 1967 at Tyson's Corner; and for the same months plus May 1967 at Silver Hill. See Table 2.

Table 2. PERCENT OF TOTAL HOURS OF INVERSIONS BELOW FEET IN WASHINGTON, D.C., AREA FROM 1966-1967 TOWER DATA (PERCENT)

	Winter	Spring	Summer	Fall
Silver Hill	28	32	30	43
Tysons Corner, Va.	33	29	46	40

The data are not strictly comparable because the sampling periods vary, the radiosonde data are from twice daily observations for surface to 500 feet, and the tower data are from hourly observations for surface to 300 feet. The combined radiosonde and tower data strongly indicate, however, that the Washington area experiences low-level inversions about 40 percent of the time in the fall, about 35 percent of the time in the winter, and about 30 percent of the time in spring and summer.

The time inversion dissipates was recorded for the months January through April 1967 for Tysons Corner and January through June 1967 for Silver Hill and are presented in Figure 4. Inversions most frequently dissipate about an hour after sunrise and form about an hour before sunrise. Some scatter in the times of marked change in stability is the result of variations in cloud cover, wind speed, and passing synoptic-scale weather features.

Stability information is presently available only from Sterling, Virginia. This rural location may or may not provide adequate low-level stability information for air pollution in the urban metropolitan area. To test how well low-level data from Sterling fit stability data at the tower locations, correlation coefficients were computed between the low-level lapse rate at Sterling and the lapse rate at the towers. They are presented in Table 3.

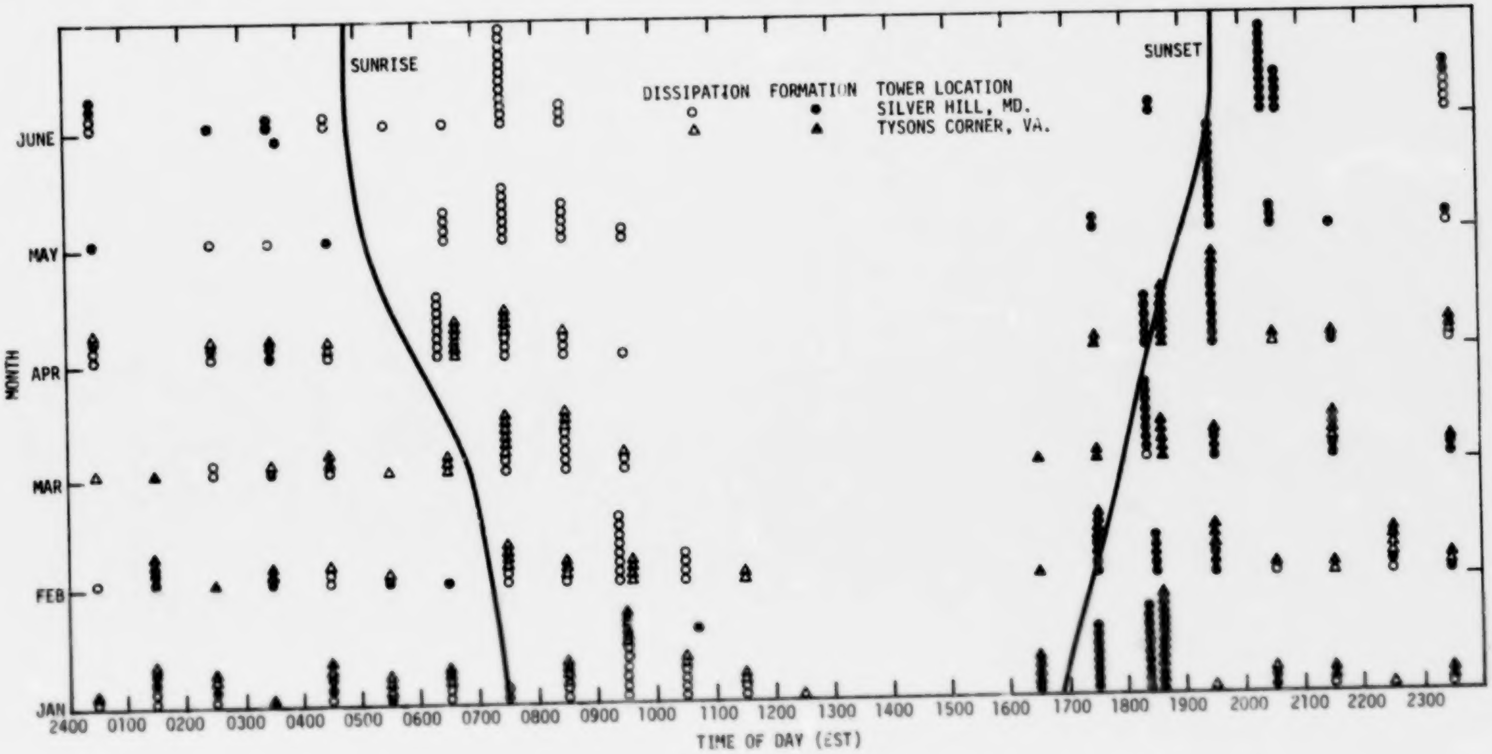


Figure 4. Monthly variation in the time of inversion dissipation and formation in the Washington, D.C., area determined from vertical temperature-difference data from 293' to 5' for the period January-June 1967, collected at the Silver Hill, Md., and Tyson's Corner, Va., towers.

Table 3. CORRELATION COEFFICIENTS BETWEEN STERLING RADIOSONDE LAPSE RATE NEAR SURFACE AND LAPSE RATE FROM SURFACE TO 300 FEET AT SILVER HILL AND TYSONS CORNER TOWERS

	Sterling versus Silver Hill		Sterling versus Tysons Corner	
	N	r	N	r
Jan. 1966	61	0.76	59	0.75
Jan.-Feb. 1967	165	0.77	116	0.73
Apr. 1966	52	0.11	60	[illegible]
Mar.-May 1967	116	0.51	124	0.51
July 1966	59	0.41	61	0.03
Oct. 1966	61	0.69	62	0.59

N = Number of observations r = Correlation coefficient

Correlations for winter and fall are reasonably high; those for spring and summer are poor. Sterling stability data are apparently inadequate for use in estimating probable pollution concentrations in spring and summer, but are probably satisfactory for use during winter and fall.

URBAN HEAT ISLAND

All meteorological elements are influenced to some extent by cities. There are several causes for the differences between urban and nearby rural climates. The reflection, radiation, and evaporation characteristics of the swamps, meadows, forests, and fields typical of rural areas are quite different from corresponding characteristics of the buildings and streets of asphalt, brick, concrete, and steel in the cities. The roughness of the surface varies between rural and urban areas. Winds are usually somewhat stronger in the rural areas. The combustion processes that take place in the city emit a sizeable quantity of heat. Finally, the dusts, gases, and vapors emitted in the city change the composition of the urban atmospheres.

Woolum[14] has made detailed analyses of maximum and minimum temperatures at 13 to 29 points in the metropolitan Washington area. He has quite vividly shown that minimum temperatures in rural areas average 4°F to 5°F cooler than those in the vicinity of the Washington National Airport. His studies show that maximum temperatures tend to be higher in the northwest portion of the District near the Potomac River and in the northeast portion along the Anacostia River.

The variation in geographical positions of the warmest nighttime areas and the warmest daytime areas indicates that an intra-urban flow is imposed by the city upon the general flow of the atmosphere over the metropolitan area. Therefore, the urban heat island effect tends to cause air pollution to ebb and flow interstate in the metropolitan area absent of other meteorological conditions. An analysis of wind data at the Dulles International Airport, Washington National Airport, Andrews Air Force Base, Suitland and CAMP stations, Friendship International Airport and the towers at Silver Hill and Tysons Corner did not reveal a consistent circulation that might be attributed to the variations in temperatures.

The nighttime stability in the city center should be less and inversions and stable layers more frequently elevated than in rural areas.[16,17] Pollutants emitted at building-top level in the city would tend to accumulate somewhat above street level and then be brought to the surface the following morning. In rural areas it would be somewhat easier to emit pollutants above the low-lying inversion, where they would be susceptible to better dispersion.

SUMMARY

It may be said that topographic or meteorological conditions conducive to the accumulation and interstate transport of air pollution can occur in the Washington metropolitan area. However, the topography des not markedly restrict free flow of the atmosphere throughout the area. The Washington area may experience on the average one or two prolonged stagnation episodes per year. Low-level inversions occur about one-third of the time and calm winds about 5 percent of the time.

III. PROJECT DESIGN

Pursuant to the objectives and scope of the Interstate Washington, D. C., Metropolitan Area Air Pollution Abatement Activity, a project was designed to fulfill the requirements presented below.

An air quality monitoring network, shown in Figure 5, was established consistent with existing or planned monitoring sites to sense the impact on receptor areas of primary area sources and point sources. The network was oriented with the wind directions usually encountered during the study period. A more detailed description of the network is presented in Appendix B.

A special investigations capability was established to provide sulfur dioxide traversing in the area, source testing at selected sites, and short-term meteorological measurements.

An emissions inventory was conducted to locate and quantify sulfur oxides, nitrogen oxides, particulate, carbon monoxide, and hydrocarbon emissions from industrial, governmental, commercial, mobile, and domestic sources. The inventory was to provide the following: (1) positive evidence of the existence of source emissions within the study area and definitions of their locations, magnitudes, and relative contributions of pollutants; (2) data for calculations that would demonstrate interstate transportation of pollutants and the magnitude of the impact of these emissions at selected receptor sites; and (3) information on present fuel-use distributional patterns and industrial emissions. The technique utilized is a modified rapid survey method that results in a zone-oriented data presentation with emissions reported for minimum, average, and maximum degree-days. A more detailed description of the procedure is included in Appendix C.

A system for collecting meterological data was established that would be consistent with existing observation stations, including National and Dulles airports and the micrometerological towers at Silver Hill and Tysons Corner. The system provided surface wind and other routine observations necessary for proper interpretation of the air quality monitoring data. The meterological data were also used to determine the "representativeness" of the 1967 sampling period, relative to past years.

A data processing and analysis system was established to coordinate the acquisition of all types of data generated or collected during this activity and to summarize and analyze these data in standard format by routine techniques. This system and the techniques utilized are described in detail in Appendix A.

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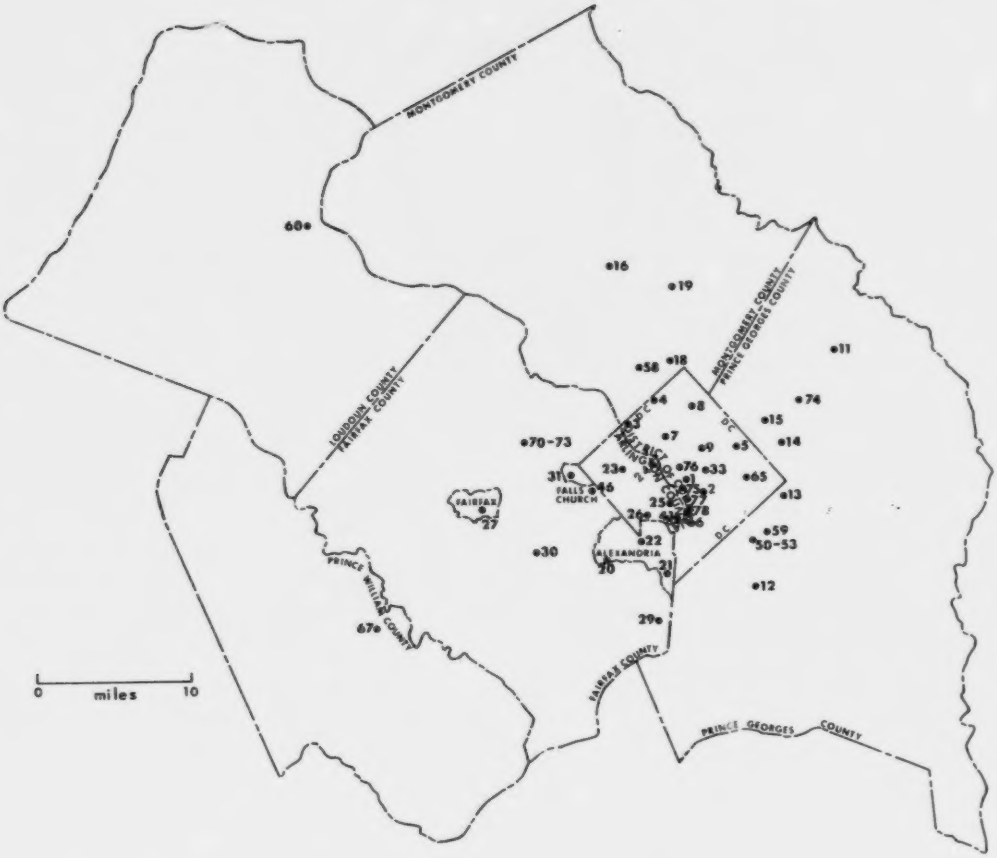
MONTGOMERY COUNTY
60
16
19
MONTGOMERY COUNTY
PRINCE GEORGES COUNTY
11
58
18
74
64
8
D.C.
15
DISTRICT OF COLUMBIA
ARLINGTON
7
9
5
14
70-73
23
76
33
65
31
FALLS CHURCH
46
1
2
13
FAIRFAX
27
25
77
78
26
22
59
50-53
30
ALEXANDRIA
20
21
12
LOUDOUIN COUNTY
FAIRFAX COUNTY
PRINCE WILLIAM COUNTY
67
29
FAIRFAX COUNTY
0
miles
10
PRINCE GEORGES COUNTY

Figure 5. Washington area air quality monitoring network.

IV. RESULTS OF COMPREHENSIVE SURVEY

A comprehensive survey of air pollution in the Washington, D. C., metropolitan area was conducted during the period January through July, 1967. This survey included a measurement of air quality, air pollution emissions, meteorology, and effects of air pollutants by the local air pollution control agencies and the on-site staff of the Abatement Program, National Center for Air Pollution Control. Most of the data presented in this report was generated in the course of the comprehensive survey. Available air quality and meteorological data for other periods of time and from sources other than agencies participating directly in the comprehensive survey have been used to extend the survey data and to assist in its interpretation.

PARTICULATE POLLUTANTS

Suspended Particulate Concentration

Atmospheric suspended particulate concentrations were measured with high-volume air samplers at ten locations. Samples were collected over 24-hour periods starting at midnight. Data obtained are reported in micrograms per cubic meter ($\mu g/m^3$) and are summarized in Table 4. Highest geometric and arithmetic mean concentrations for the period of observation were measured near Kenilworth Dump, and lowest geometric and arithmetic mean concentrations were measured at Seven Corners, Virginia. Maximum 24-hour concentrations exceeding 300 $\mu g/m^3$ were measured near Kenilworth Dump and at the Alexandria Sewage Plant station. Suspended particulate concentrations exceeded 125 $\mu g/m^3$ more than 10 percent of the time at Hyattsville, CAMP, Kenilworth Dump and Alexandria Sewage Plant stations. Geometric mean concentration for the period of observation exceeded 75 $\mu g/m^3$ at five stations and exceeded 100 $\mu g/m^3$ at one station.

Washington, D. C. is included in the National Air Sampling Network (NASN). NASN is operated jointly by the National Center for Air Pollution Control of the Public Health Service, and state and local air pollution control agencies. Samples for suspended particulates ordinarily have been obtained on a biweekly basis. The data obtained in Washington, D. C., are summarized in Table 5.

Table 4. CUMULATIVE PERCENT FREQUENCY OF OCCURRENCE OF DAILY AVERAGE SUSPENDED PARTICULATE CONCENTRATION

Station number	Station location	Operating period	No obs	Concentration, $\mu g/m^3$												
				Min value	Percent of time ≥ stated value							Max value	Arith mean	Std dev	Geom mean	Geom std dev
					90	70	50	30	16	10	1					
14	Cheverly	3/67-8/67	56	28	43	59	74	92	110	122	170	179	78	31	72	1.5
15	Hyattsville	2/67-4/67	44	44	52	74	92	113	134	145	172	172	97	35	91	1.5
21	Alexandria	2/67-8/67	106	27	46	59	70	81	92	98	116	132	70	20	67	1.3
33	CAMP	2/67-8/67	109	41	64	82	96	112	130	141	185	202	101	14	96	1.4
41	Nat'l Airport	2/67-7/67	92	20	44	58	70	84	97	105	134	137	71	15	68	1.4
46	Seven Corners	2/67-8/67	105	26	40	50	59	68	78	85	111	111	61	19	59	1.4
58	NIH	3/67-8/67	72	26	40	52	62	74	86	94	123	125	65	22	62	1.4
59	Suitland	2/67-8/67	102	29	54	71	84	99	110	119	139	143	86	25	82	1.4
65	Kenilworth Dump	2/67-5/67	38	55	77	110	142	180	215	240	315	317	147	64	134	1.6
A	Alexandria Sewage Plant[a]	10/66-5/67	67	23	44	62	80	100	123	140	195	324	91	55	80	1.7

[a] Data obtained by the Alexandria Health Department and the Metropolitan Washington Council of Governments.

Table 5. SUMMARY OF NATIONAL AIR SAMPLING NETWORK DATA FOR SUSPENDED PARTICULATES IN WASHINGTON, D. C.

Year	No. Samples	Concentration, μg/m^3		% of time 150 μg/m^3 exceeded
		Maximum	Arithmetic mean	
1958	24	177	111	17
1959	22	231	103	19
1960	22	242	135	28
1961	24	268	128	30
1962	23	354	143	30
1963	25	231	116	20
1964	26	187	84	<10
1965	24	199	91	<10
1966	25	216	77	<10
1967(Jan-June)	13	170	99	--

Respirable Dust

A series of respirable dust samples of 24-hour duration were collected at the CAMP location to represent the core area of the city and at Alexandria to represent a residential area. Commercially available cyclone dust separators that simulate the particle collection characteristics of the upper respiratory system were used as the initial stage of two-stage samplers with high-volume air samplers employing glass-fiber filters used as the second or respirable dust-collection stage.[17] The equivalent size distribution of particles that penetrate the cyclones and are retained on the filters is in close agreement with the size distribution of the respirable dust fraction as defined by the Office of Health and Safety, U.S. Atomic Energy Commission.

Data obtained on atmospheric respirable dust concentrations are summarized in Table 6. Respirable dust levels were higher at the CAMP location than at the Alexandria station. Concentrations exceeded 61 μg/m^3 on 10 percent of the samples collected at the CAMP station and concentrations exceeded 45 μg/m^3 on 10 percent of the samples collected at the Alexandria station. Arithmetic mean concentrations measured at the CAMP and Alexandria stations were 44 and 32 μg/m^3, respectively.

On days when both respirable and total suspended particulate were measured, respirable dust in the atmosphere averaged 45 percent of the total particulates (Table 7). The maximum was 76 percent. There was little difference noted in percentage of respirable dust at the two sampling locations.

Suspended Particulate - Soiling Index

Soiling index was measured at three locations using AISI sequential filter-paper tape samplers. Data obtained over 2-hour averaging times are reported in

Table 6. CUMULATIVE PERCENT FREQUENCY OF OCCURRENCE OF DAILY AVERAGE RESPIRABLE DUST CONCENTRATION

Station number	Station location	Operating period	No. obs	Concentration, $\mu g/m^3$											
				Min. value	Percent of time $\geq$ stated value						Max value	Arith mean	Std dev	Geom mean	Geom std dev
					90	70	50	30	16	10					
21	Alexandria	4/67-8/67	34	13	17	24	32	39	43	45	48	32	10	30	1.4
33	CAMP	4/67-8/67	50	17	30	37	42	50	57	61	66	44	12	42	1.3

Table 7. PERCENT RESPIRABLE DUST OF TOTAL SUSPENDED PARTICULATE

Station number	Station location	No. obs	Percentage value		
			Minimum	Average	Maximum
21	Alexandria	34	25	46	71
33	CAMP	50	20	44	76

Cohs per 1,000 lineal feet and are summarized in Table 8. Arithmetic mean soiling index for the period of observation was highest at the Paint and Varnish Association, 1500 Rhode Island Avenue, N.W. (0.5 Coh /1000 ft). Values exceeding 0.9 Coh /1000 feet occurred most frequently (11%) at the Paint and Varnish Association Station and least frequently (3%) at Alexandria (Table 9).

Settleable Particulates - Dustfall

Settleable particulate was measured on a monthly basis from January to July 1967, at 36 sampling stations using dustfall collectors. Data obtained are reported in tons per square mile per month (tons/mi^2 - mo) and are summarized in Table 10. The dates of observation are inclusive; in some cases, however, the number of samples listed in the table is less than would be expected for the period stated. Arithmetic mean values for the period of observation exceeded 20 tons/mi^2 - mo at stations 2, 24, 26, and 41. Arithmetic mean values exceeded 15 tons/mi^2 - mo at eight sites. Maximum monthly dustfall exceeded 40 tons/mi^2 - mo at stations 2, 9, and 26. Maximum monthly dustfall exceeded 25 tons/mi^2 - mo at eight sites.

GASEOUS POLLUTANTS

Sulfur Dioxide

Atmospheric sulfur dioxide (SO_2) concentrations were measured at seven locations. Two-hour average concentration was measured at Cheverly and Seven Corners, using automatic sequential samplers and the p-rosaniline spectrophotometric method of detection. Atmospheric concentrations were measured at all other stations by use of continuous-monitoring electroconductivity analyzers, and data obtained were averaged over 1-hour periods. Data obtained are summarized in Table 11. Arithmetic mean concentrations for the periods of observation specified for each station ranged from 0.02 to 0.04 ppm. Hourly sulfur dioxide concentrations exceeded 0.13 ppm for 1 percent of the time at Cheverly, Hyattsville, and Seven Corners. Greatest arithmetic mean concentration occurred at Hyattsville, and the second greatest mean occurred at Seven Corners. Hourly average concentrations did not excced 0.20 ppm for 1 percent of the time at any of the sampling stations. The maximum hourly average concentration was 0.22 ppm.

Cumulative percent frequency of occurrence of daily average concentrations for 1967 data appear in Table 12. Daily average concentrations exceeded 0.1 ppm for 2 percent of the time at Seven Corners (Table 13).

Review of the sulfur dioxide data revealed an apparent seasonal trend in concentration levels. Since the bulk of the data was collected during the Spring and Summer of 1967, information from the CAMP station was used to estimate the concentration levels that would be expected during the winter season and also for the entire

Table 8. CUMULATIVE PERCENT FREQUENCY OF OCCURRENCE OF BI-HOURLY SOILING INDEX

Station number	Station location	Operating period	No. obs	Soiling Index, Cohs/1000 lineal feet								Max value	Arith mean	Std dev
				Min. value	Percent of time ≥ stated value									
					90	70	50	30	16	10	1			
21	Alexandria	4/67-6/67	625	<0.1	<0.1	0.1	0.2	0.3	0.4	0.6	1.3	1.7	0.3	0.3
59	Suitland	3/67-8/67	1628	<0.1	<0.1	0.2	0.3	0.5	0.6	0.7	1.3	3.0	0.4	0.3
76	Paint and Varnish Assoc.	5/67-8/67	569	<0.1	0.1	0.3	0.4	0.6	0.8	0.9	1.6	2.6	0.5	0.3

Table 9. PERCENT OF SOILING INDEX VALUES WITHIN CERTAIN GIVEN RANGE

Range of soiling index Cons/1000 lineal feet	Station numbers		
	21	59	76
0.0 - 0.4	80	63	47
0.5 - 0.9	17	32	42
1.0 - 1.9	3	5	11
2.0 - 2.9	0	< 1	< 1
3.0 - 3.9	0	< 1	0
4.0 plus	0	0	0

Table 10. SETTLEABLE PARTICULATE - DUSTFALL

Station number	Station location	Operating period	No. of obs	tons/mi^2 - mo		Arith mean
				Min.	Max.	
1	Treasury Building	1/67-7/67	6	7	20	14
2	Capitol Hill	1/67-7/67	6	5	59	21
3	Delecarla Reservoir	1/67-7/67	6	2	13	7
4	Chevy Chase	1/67-7/67	5	3	26	16
5	St. Frances De Sales	1/67-6/67	6	8	13	12
7	Footer Building	1/67-7/67	6	3	18	12
8	Basil Building	1/67-7/67	7	8	14	10
9	McMillan Reservoir	1/67-7/67	6	8	43	18
11	Greenbelt H.S.	1/67-7/67	7	9	23	15
12	R.B. Tanny H.S.	1/67-7/67	5	5	26	13
13	Capital Heights	1/67-7/67	7	2	10	7
14	Cheverly	1/67-7/67	3	10	21	16
15	Hyattsville	1/67-7/67	7	8	22	16
16	Rockville Health Dept.	1/67-7/67	7	5	13	7
18	Rosemary Hill	1/67-7/67	7	5	16	9
19	Glenmont	1/67-7/67	7	3	12	6
20	Cameron Station	1/67-7/67	7	5	16	10
21	Alexandria	1/67-7/67	7	6	29	13
22	T.C. Williams H.S.	1/67-7/67	7	6	17	11
23	Mason Center	1/67-7/67	7	4	11	7
24	Drew	1/67-7/67	7	16	38	25
25	Fish Exchange Building	1/67-7/67	7	7	21	14
26	Gaslight Building	1/67-7/67	7	17	106	44
27	Fairfax Library	1/67-7/67	7	6	22	9
29	Westgate	1/67-7/67	7	4	10	7
30	Belvedere School	1/67-7/67	7	4	9	6
31	Falls Church Bank	3/67-7/67	5	10	18	14
33	CAMP	1/67-6/67	6	11	25	20
41	National Airport	3/67-7/67	5	13	38	23
46	Seven Corners	2/67-7/67	6	5	16	11
58	N I H	3/67-7/67	5	5	13	9
59	Suitland	2/67-7/67	6	6	20	11
60	Loudoun Co. Health Dept.	3/67-6/67	4	5	10	8
66	U.S. Naval Station	3/67-7/67	5	11	23	15
67	Manassas, Virginia	4/67-7/67	4	4	12	8
78	Park Services	3/67-6/67	4	8	15	12

Table 11. CUMULATIVE PERCENT FREQUENCY OF OCCURRENCE OF HOURLY AVERAGE SULFUR DIOXIDE CONCENTRATION

Station number	Station location	Operating period	No. obs	Concentration, ppm										
				Min. value	Percent of time ≥ stated value							Max. value	Arith mean	Std dev
					90	70	50	30	16	10	1			
14	Cheverly[a]	5/67-8/67	624	<0.01	<0.01	<0.01	0.01	0.02	0.04	0.05	0.15	0.22	0.02	0.03
46	Seven Corners[a]	2/67-8/67	1003	<0.01	<0.01	0.01	0.03	0.04	0.06	0.07	0.14	0.19	0.03	0.02
15	Hyattsville	3/67-4/67	705	< 0.01	0.01	0.03	0.04	0.05	0.06	0.07	0.15	0.21	0.04	0.02
21	Alexandria	3/67-8/67	3110	<0.01	<0.01	0.01	0.01	0.02	0.03	0.04	0.09	0.15	0.02	0.02
58	NIH	2/67-8/67	3087	< 0.01	0.01	0.01	0.02	0.03	0.03	0.04	0.08	0.18	0.02	0.02
59	Suitland	2/67-8/67	3237	<0.01	<0.01	0.01	0.02	0.02	0.03	0.04	0.07	0.15	0.02	0.02
66	U.S. Naval Station	5/67-8/67	1716	<0.01	<0.01	0.01	0.02	0.03	0.04	0.05	0.09	0.20	0.02	0.02

Table 12. CUMULATIVE PERCENT FREQUENCY OF OCCURRENCE OF DAILY AVERAGE SULFUR DIOXIDE CONCENTRATION - VARYING PERIODS - 1967

Station number	Station location	No. obs	Concentration, ppm									
			Min. value	Percent of time ≥ stated value							Max. value	Arith mean
				90	70	50	30	16	10	1		
14	Cheverly	53	<0.01	0.01	0.02	0.02	0.03	0.04	0.04	0.07	0.07	0.02
15	Hyattsville	31	<0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.01	0.09	0.04
21	Alexandria	137	<0.01	<0.01	0.02	0.02	0.03	0.04	0.04	0.06	0.06	0.02
46	Seven Corners	89	0.01	0.01	0.02	0.03	0.04	0.06	0.07	0.11	0.11	0.04
58	NIH	131	<0.01	0.01	0.02	0.02	0.03	0.04	0.04	0.07	0.07	0.02
59	Suitland	143	<0.01	0.01	0.02	0.02	0.03	0.04	0.04	0.05	0.05	0.02
66	U.S. Naval Sta.	74	<0.01	<0.01	0.02	0.02	0.03	0.04	0.05	0.06	0.06	0.02

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[a] 2-hour average concentrations

Table 13. PERCENT OF TIME CERTAIN DAILY AVERAGE SULFUR DIOXIDE CONCENTRATIONS WERE EXCEEDED-VARYING PERIODS 1967

Station number	Station location	Percent of time exceeding:		
		0.05 ppm	0.10 ppm	0.15 ppm
14	Cheverly	<1	0	0
15	Hyattsville	19	0	0
21	Alexandria	<1	0	0
46	Seven Corners	25	2	0
58	NIH	<1	0	0
59	Suitland	0	0	0
56	U.S. Naval Station	<1	0	0

year. Continuous sampling has been performed at the CAMP station for the past several years. Cumulative percent frequency of occurrence of both daily and hourly average SO_2 values were generated for the months of January, April, July, and October from 1963 through 1966. These data are shown in Tables 14 and 15. An analogous set of data was prepared for daily average SO_2 levels for the years 1965 and 1966. These data are shown in Table 16. Analysis reveals that levels in January were 3.5 to 4.0 times greater than corresponding July values. This ratio is applicable to both daily and hourly averages. Similarly, for daily averages, the yearly values were 2.0 to 2.5 times greater than the July values.

The only directly comparable data for 1967 were those for June, when CAMP levels were distributed about the same as the 4-year July cumulative frequency distributions. Summer 1967 SO_2 levels are, therefore, probably similar to the levels during the previous 4 years at this station.

Figures 6 through 12 give cumulative percent frequency of occurrence of daily average SO_2 concentrations for July 1967, except for the CAMP station where June, 1967 data are used, and projected estimates based on the above-mentioned January (winter) and yearly levels for selected stations in the study area.

Table 14. CUMULATIVE PERCENT FREQUENCY OF OCCURRENCE OF HOURLY AVERAGE SULFUR DIOXIDE CONCENTRATION AT CAMP STATION 1963-1966

Month	No. of Obs.	Concentration, ppm						
		Percent of time ≥ stated value					Max.	Arith mean
		70	50	30	10	1		
January	2139	0.04	0.07	0.09	0.14	0.26	0.37	0.08
April	2382	0.02	0.03	0.05	0.08	0.15	0.35	0.05
July	1903	0.01	0.01	0.02	0.04	0.08	0.11	0.02
October	2725	0.01	0.02	0.05	0.09	0.21	0.46	0.04

Table 15. CUMULATIVE PERCENT FREQUENCY OF OCCURRENCE OF DAILY AVERAGE SULFUR DIOXIDE CONCENTRATION AT CAMP STATION-1963-1966

Month	No. of Obs.	Concentration, ppm						
		Percent of time ≥ stated value					Max.	Arith mean
		70	50	30	10	1		
January	91	0.05	0.08	0.09	0.13	0.21	0.22	0.08
April	103	0.03	0.04	0.05	0.07	0.09	0.12	0.05
July	81	<0.01	0.01	0.02	0.04	0.07	0.08	0.02
October	85	0.02	0.04	0.06	0.09	0.13	0.14	0.05

Table 16. CUMULATIVE PERCENT FREQUENCY OF OCCURRENCE OF DAILY AVERAGE SO_2 CONCENTRATION CAMP DATA OF 1965 and 1966.

	Concentration							
		Percent of time ≥ stated ppm value						
No. of Obs.	Min. value	70	50	30	10	01	Max.	Arith. mean
457	0.01	0.02	0.04	0.06	0.09	0.14	0.25	0.05

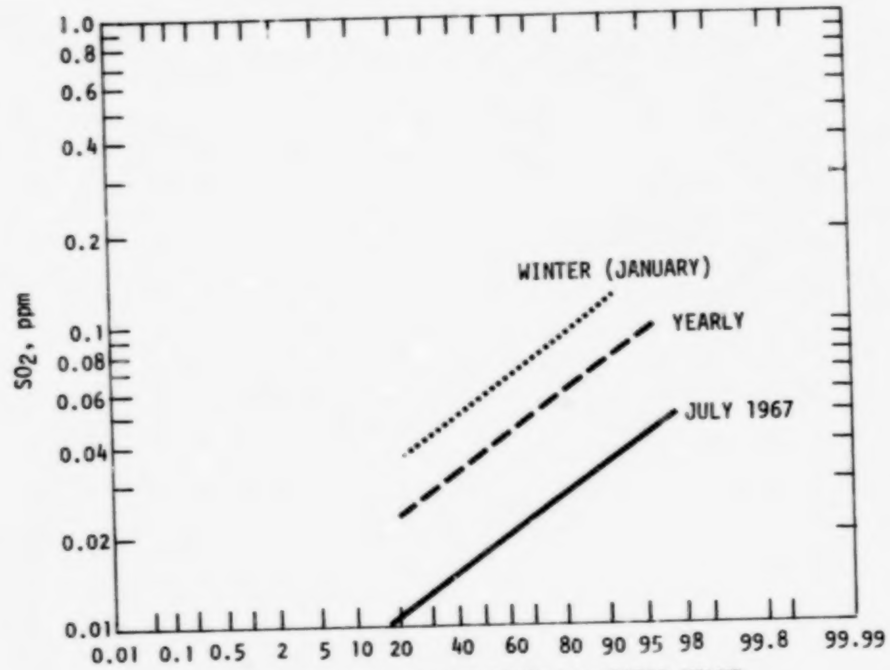

Figure 6. Cumulative percent frequency of occurrence of daily SO_2 concentrations for July 1967 and estimated yearly and winter levels at Cheverly.

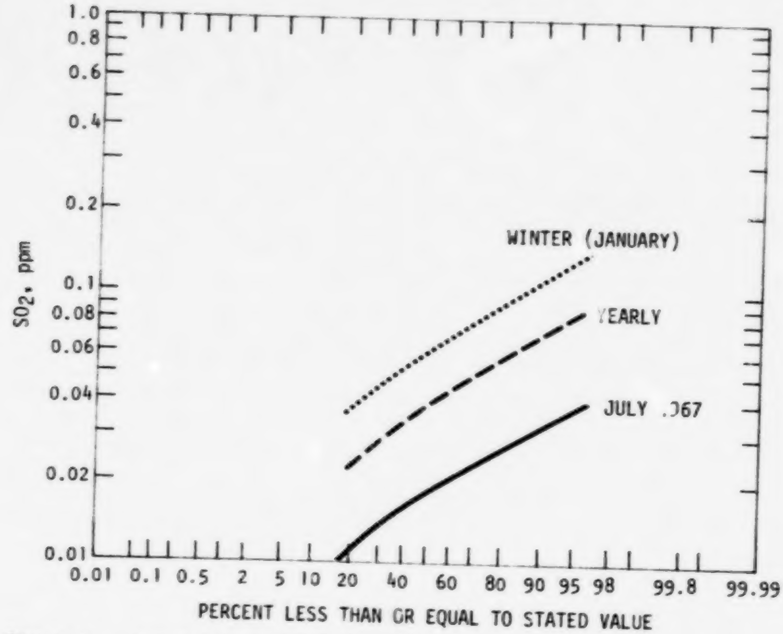

Figure 7. Cumulative percent frequency of occurrence of daily SO_2 concentrations for July 1967 and estimated yearly and winter levels at Alexandria.

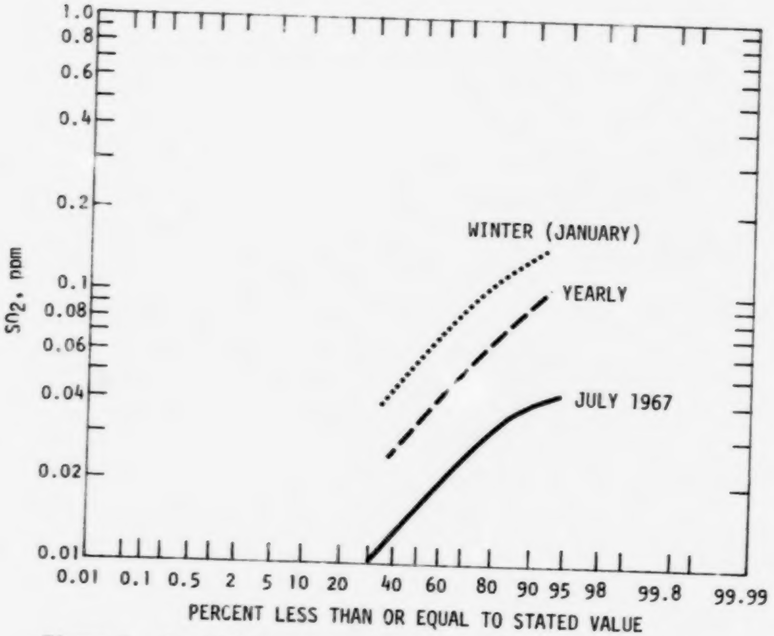

Figure 8. Cumulative percent frequency of occurrence of daily SO_2 concentrations for June 1967 and estimated yearly and winter levels at CAMP station.

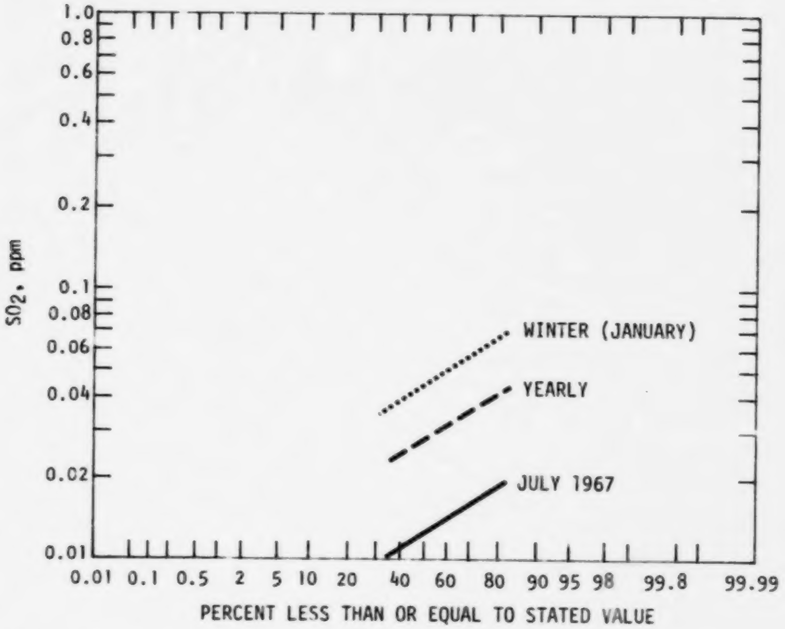

Figure 9. Cumulative percent frequency of occurrence of daily SO_2 concentrations for July 1967 and estimated yearly and winter levels at Seven Corners.

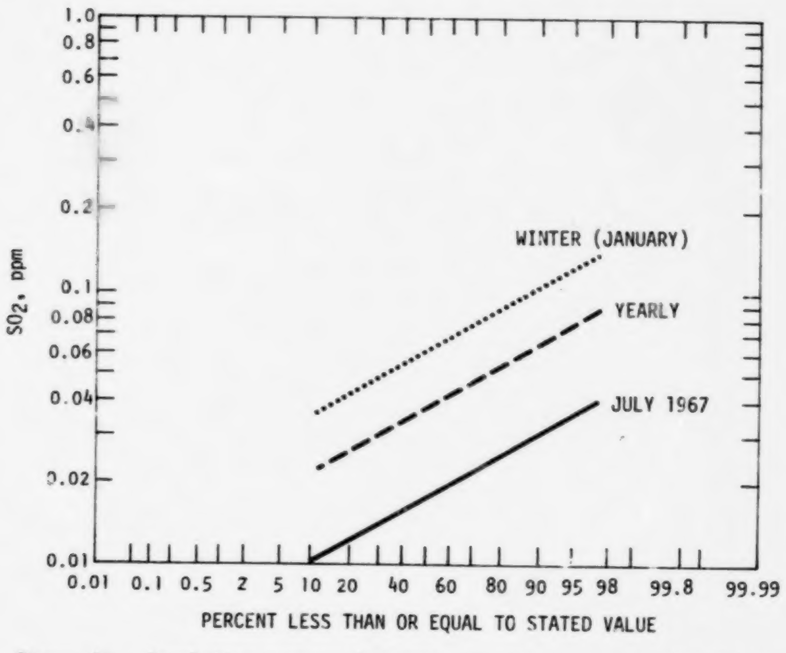

Figure 10. Cumulative percent frequency of occurrence of daily SO_2 concentrations for July 1967 and estimated yearly and winter levels at National Institutes of Health.

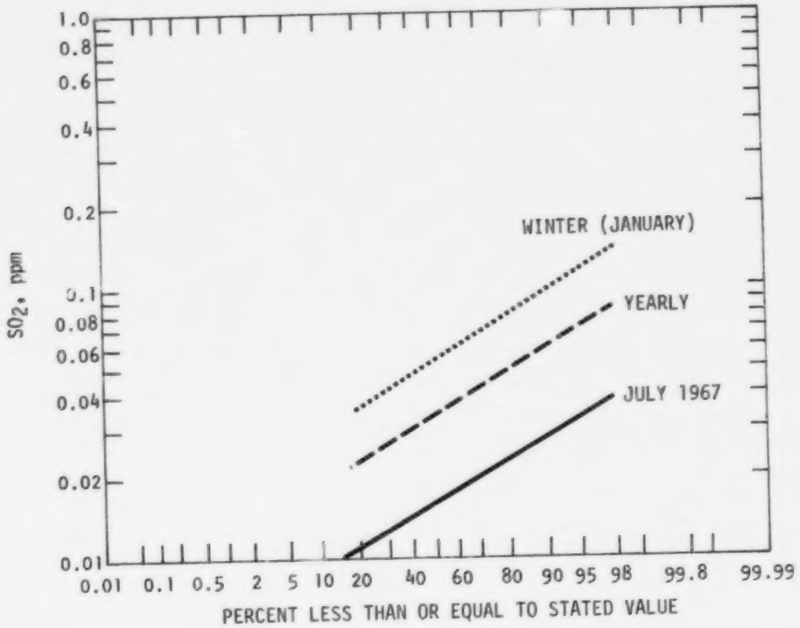

Figure 11. Cumulative percent frequency of occurrence of daily SO$_2$ concentrations for July 1967 and estimated yearly and winter levels at Suitland.

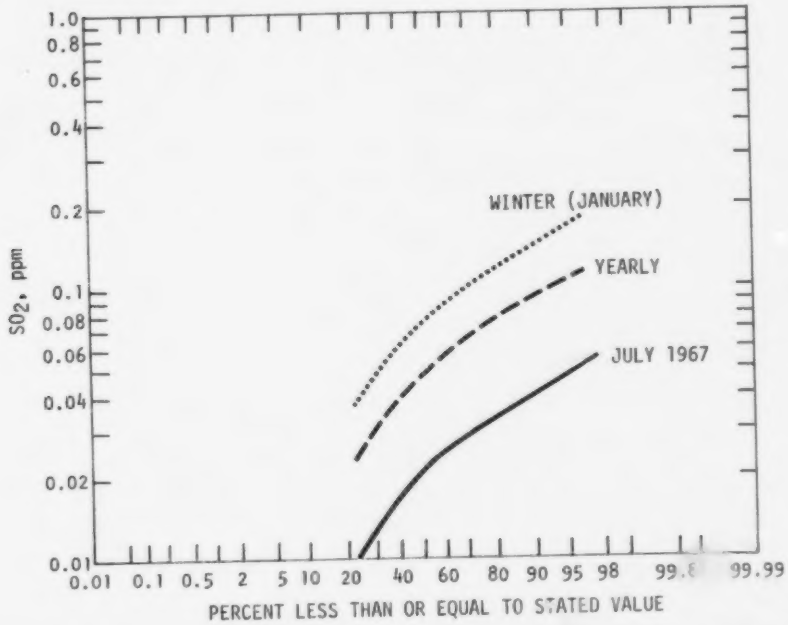

Figure 12. Cumulative percent frequency of occurrence of daily SO$_2$ concentrations for July 1967 and estimated yearly and winter levels at U.S. Naval Station.

Sulfation

Sulfation rate was determined at 28 sampling stations from February to July, 1967 using lead peroxide candles. Data obtained are reported in milligrams of sulfur trioxide per 100 square centimeters per day and are summarized in Table 17. Sulfation rate, a measure of sulfur dioxide dosage, is used to estimate the monthly average concentration of atmospheric sulfur dioxide.

Table 17. MONTHLY SULFATION DATA

Station	Station Location	Obs. period	No. Obs	Concentration, mg $SO_3/100cm^2$-day			
				Min.	Max.	Arith Mean	Geom Mean
1	Treasury Building	4/67-7/67	4	0.9	1.6	1.2	1.2
2	Capitol Hill	3/67-7/67	3	1.2	2.4	1.6	1.6
5	St. Frances de Sales	2/67-6/67	4	<0.1	1.2	0.7	0.5
7	Footer Building	2/67-7/67	5	0.6	1.5	1.0	0.9
8	Basil Building	4/67-7/67	4	0.6	1.4	0.9	0.9
11	Greenbelt H.S.	2/67-7/67	6	0.4	1.2	0.7	0.6
13	Capital Heights	2/67-7/67	5	0.3	1.6	0.8	0.6
14	Cheverly	2/67-7/67	6	0.6	3.2	1.7	1.4
15	Hyattsville	2/67-7/67	6	0.4	2.0	1.2	1.0
16	Rockville Health Dept.	2/67-7/67	6	0.2	0.9	0.5	0.4
18	Rosemary Hill	2/67-7/67	6	0.3	1.8	0.8	0.7
20	Cameron Sta.	2/67-7/67	6	0.2	1.0	0.6	0.5
21	Alexandria	2/67-7/67	5	0.4	6.4	1.8	1.0
24	Drew	3/67-7/67	5	<0.1	1.8	0.9	0.4
27	Fairfax Library	2/67-7/67	6	0.2	0.7	0.4	0.4
29	Westgate	3/67-6/67	4	0.2	0.6	0.5	0.4
30	Belvedere School	2/67-7/67	5	0.2	0.6	0.4	0.4
33	CAMP	1/66-8/67	20	0.7	3.0	1.4	1.3
41	National Airport	3/67-7/67	5	0.5	1.7	1.0	0.9
46	Seven Corners	2/67-7/67	6	0.3	1.9	1.1	0.8
58	NIH	3/67-7/67	5	0.2	0.8	0.5	0.4
59	Suitland	2/67-7/67	6	0.4	2.0	1.1	0.9
60	Loudoun Co. Health Department	2/67-8/67	5	0.1	1.0	0.4	0.3
66	U. S. Naval Station	3/67-7/67	5	0.5	1.2	0.9	0.8
67	Manassas, Virginia	4/67-7/67	4	<0.1	0.5	0.2	0.1
78	Park Services	3/67-8/67	6	0.6	1.5	0.9	0.9

Relative geographic distribution of sulfation was determined from isopleths of arithmetic mean values (Figure 13). Highest sulfation values (>1.5) were centered in an area stretching from northeastern Washington, D. C., to northwest Prince Georges County. Second highest values (1.1 to 1.5) were observed in an belt oriented in an east-northeasterly direction and stretching from Falls Church, Virginia, to Riverdale, Maryland. Lowest sulfation values (< 0.6) were observed in outlying areas located approximately equidistant from the center of highest sulfation.

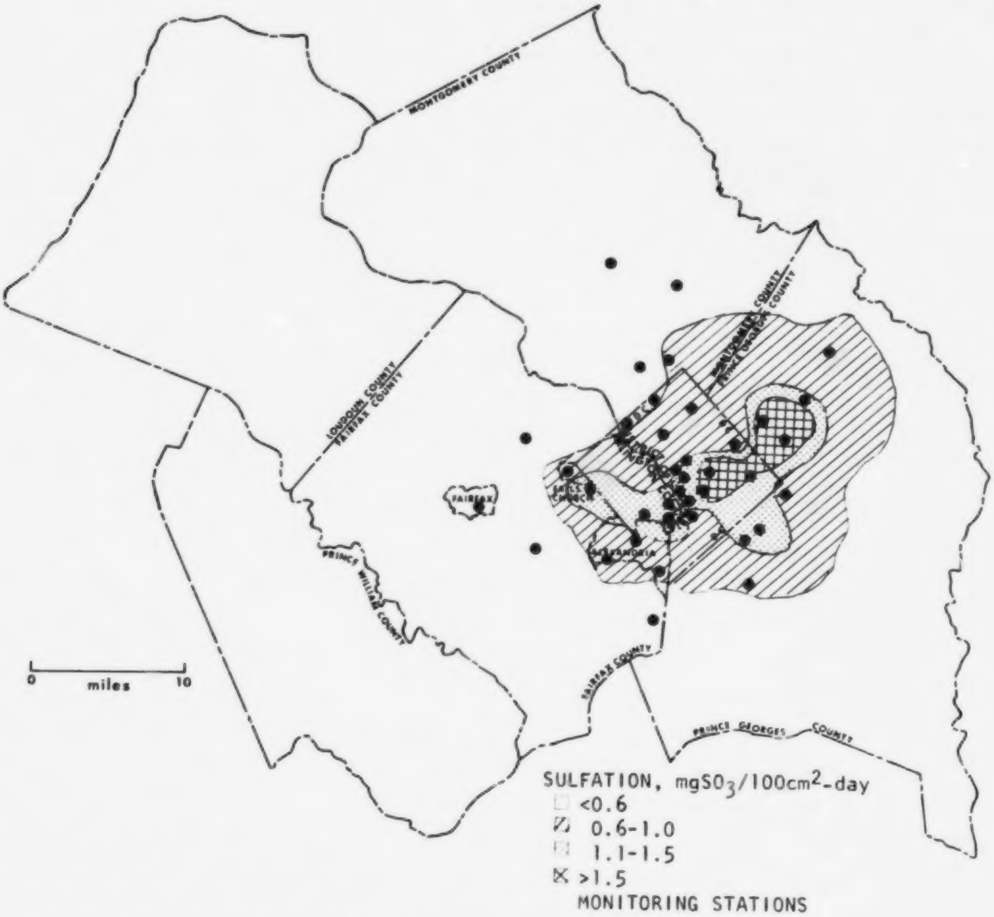
MONTGOMERY COUNTY
LOUDOUN COUNTY
FAIRFAX COUNTY
MONTGOMERY COUNTY
PRINCE GEORGES COUNTY
FAIRFAX
FALLS CHURCH
ALEXANDRIA
PRINCE WILLIAM COUNTY
FAIRFAX COUNTY
PRINCE GEORGES COUNTY
0 miles 10
SULFATION, mgSO3/100cm2-day
<0.6
0.6-1.0
1.1-1.5
>1.5
MONITORING STATIONS

Figure 13. Geographic distribution of sulfation.

The average sulfation value for all sites was used to determine monthly variation in sulfation. Sulfation rates decreased progressively from February to July as depicted in Figure 14. Sulfation rate for February and March is about three times greater than that of June and July.

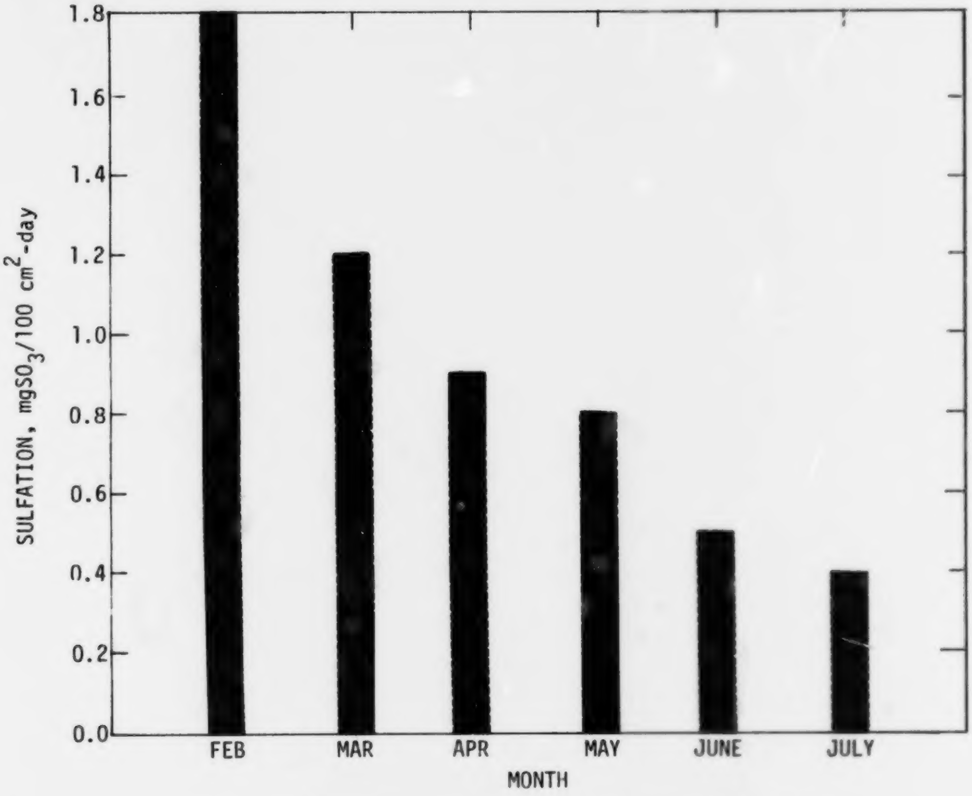

Figure 14. Monthly variation in sulfation from February to July 1967.

Carbon Monoxide

Carbon monoxide concentrations were measured at National Institute of Health, Alexandria, and Suitland from February to August, 1967, using continuous-monitoring non-dispersive infrared analyzers. Cumulative percent frequency distribution of hourly average carbon monoxide concentrations for the period of observation are presented in Table 18. Fifty percent of the values exceeded 3 parts per million (ppm) at the Alexandria, NIH, and Suitland stations, respectively; 10 percent of the values exceeded 7 ppm and 1 percent of the values exceeded 11 ppm, at the same stations. Arithmetic means at all stations were 5 ppm. The percent of time that concentrations exceeded 5, 10, and 15 ppm is indicated in Table 19.

Hourly carbon monoxide concentrations measured at the CAMP station from 1963 to 1967 were summarized for the months of January, April, July, and October (Table 20). These months were selected to represent the four seasons. During

Table 18. CUMULATIVE FREQUENCY OF OCCURRENCE OF HOURLY AVERAGE CARBON MONOXIDE CONCENTRATIONS

Station no.	Station location	Obs. period	No. obs.	Concentration, ppm										
				Min. value	Percent of time > stated value							Max. value	Arithmetic mean	Arithmetic std dev
					90	70	50	30	16	10	1			
21	Alexandria	2/67-8/67	2512	<1.0	2	4	5	6	7	8	13	24	5	2.5
58	NIH	3/67-8/67	3256	<1.0	2	3	4	6	7	9	16	29	5	3.0
59	Suitland	2/67-8/67	1702	<1.0	2	3	5	6	8	9	12	15	5	2.6

Table 19. PERCENT OF TIME CERTAIN HOURLY AVERAGE CARBON MONOXIDE CONCENTRATIONS WERE EXCEEDED FROM FEBRUARY THROUGH AUGUST, 1967

Station number	Station location	Percent of time exceeded:		
		5 ppm	10 ppm	15 ppm
21	Alexandria	48	6	<1
58	NIH	41	8	2
59	Suitland	47	7	<1

Table 20. CUMULATIVE PERCENT FREQUENCY OF OCCURRENCE OF HOURLY AVERAGE CARBON MONOXIDE CONCENTRATIONS AT CAMP STATION

	Years samples taken						Concentration, ppm								
								Percent of time ≥ stated value							
Month	1963	1964	1965	1966	1967	No. Obs	Min.	70	50	30	16	10	1	Max.	Arith mean
January	X			X	X	1546	1	3	4	5	6	8	14	19	5
April	X	X	X	X	X	3116	0	2	3	5	5	6	10	20	5
July	X		X	X		2161	0	2	3	4	5	6	12	27	4
October	X	X	X	X		2751	0	3	5	6	9	11	23	38	6

Table 21. ROUTE DESCRIPTION FOR IN-TRAFFIC CARBON MONOXIDE DATA

Route	Route No.	Description
Center City	1.	Start at Independence and 14th Avenues. Follow 14th Avenue north to K. Street. Turn left on K. Street and proceed to 18th Street. Turn north on 18th Street and proceed to Connecticut Avenue. Turn left on Connecticut Avenue. Route terminates at Dupont Circle.
	2.	Begin at Dupont Circle. Proceed south on 19th Street to K. Street. Follow K. Street to 14th Street. Follow 14th Street to Independence Avenue.
Arterial		Begin at Dupont Circle and follow Connecticut Avenue to Chevy Chase Circle. Go around Circle and return to Dupont Circle via Connecticut Avenue.
Expressway		Start at Shirlington Entrance to Shirley Memorial Highway I 95. Proceed south to Route 236. Leave highway. Cross over I 95 on 236 and then proceed north on Shirley Highway into District. Cross 14th Street at bridge and proceed north on 14th Street. Route terminates at 14th Street and C. Street.

October, carbon monoxide concentrations exceeded 10 ppm for 10 percent of the time and exceeded 22 ppm for 1 percent of the time. These data indicate that average carbon monoxide concentration is highest during the fall season.

A study to determine the levels of carbon monoxide to which people are exposed while inside motor vehicles in transit during rush hours was conducted by the Air Quality and Emission Data Program, National Center for Air Pollution Control from April 15 to April 27, 1967. Atmospheric samples inside a motor vehicle were monitored continuously for carbon monoxide concentration using a nondispersive infrared analyzer. The routes followed are described in Table 21. Data obtained are summarized in Table 22. On the average, the carbon monoxide concentrations measured were more than 3 times those measured at fixed sampling stations in the in the Washington, D. C., metropolitan area. Carbon monoxide levels measured for the center city route were higher than for the arterial or expressway routes.

Oxidants

Oxidant concentrations in the atmosphere were measured at seven locations using continuous-monitoring instrumentation. The Mast Coulometric Analyzer was employed at Alexandria, Seven Corners, and Suitland; the Technicon Colormetric Analyzer, at Cheverly and Hyattsville; and the Beckman Colormetric Analyzer at CAMP and NIH. Hourly oxidant concentrations measured at suburban stations are summarized in Table 23. Hourly average concentrations exceeding 0.10 ppm were measured at all stations except Suitland and concentrations exceeding 0.15 ppm were measured at Cheverly, Alexandria, and NIH. Hourly average concentrations exceeding 0.15 ppm occurred for 1 percent of the time at NIH (Table 24). Hourly average concentration exceeding 0.10 ppm occurred for more than 1 percent of the time at CAMP, Cheverly, Hyattsville and NIH.

Data on hourly average oxidant concentration measured at the CAMP station during June, July, and August for the years 1964 to 1966 are summarized in Table 25. Oxidant concentration exceeded 0.10 ppm more than 1 percent of the time during each of these months. The maximum hourly concentration measured was 0.17 ppm.

Data obtained by the Metropolitan Washington Council of Governments during June, July, and August for the years 1965-1967 are summarized in Table 26. Ten-minute samples were collected daily between the hours of 1100 and 1300. In 1965 and 1966 the phenolphthalin method of measurement was used, and in 1967 the potassium iodide method was used. Results obtained by the phenolphthalin method range from 1.5 to 2.5 times greater than the results obtained by the

Table 22. IN-TRAFFIC CARBON MONOXIDE DATA, WASHINGTON, D.C.
APRIL 15-27, 1967

Route	Average running time, min	Distance, miles	Carbon monoxide, ppm			
			No. runs	Average	10% of 5-min avg exceeds stated concentration	5-min max.
Center City[a]	15	2.2	34	26	45	93
Arterial	30	9.1	17	20	31	56
Expressway	36	17.4	17	17	34	66

[a] Data for two routes are combined.

Table 23. CUMULATIVE PERCENT FREQUENCY OF OCCURRENCE
OF HOURLY AVERAGE OXIDANT CONCENTRATIONS

Station Number	Station location	Operating period	No. obs	Concentration, ppm										
				Min. value	Percent of time ≥ stated value							Max. value	Arith. mean	Arith. std dev
					90	70	50	30	16	10	1			
14	Cheverly	5/67-8-67	1925	<0.01	<0.01	0.01	0.01	0.02	0.03	0.05	0.12	0.26	0.02	0.02
15	Hyattsville	3/67-4/67	1076	<0.01	0.01	0.02	0.03	0.04	0.06	0.07	0.10	0.13	0.03	0.02
58	N.I.H.	2/67-8/67	2909	<0.01	0.02	0.03	0.04	0.06	0.07	0.09	0.16	0.27	0.05	0.05
21	Alexandria	4/67-8/67	1425	<0.01	<0.01	0.01	0.02	0.03	0.04	0.05	0.10	0.18	0.02	0.02
46	Seven Corners	2/67-7/67	2202	<0.01	0.01	0.02	0.02	0.03	0.04	0.04	0.07	0.11	0.02	0.02
59	Suitland	2/67/7/67	2627	<0.01	<0.01	0.01	0.02	0.02	0.03	0.03	0.05	0.08	0.02	0.01

Table 24. PERCENT OF TIME THAT SELECTED HOURLY AVERAGE OXIDANT CONCENTRATIONS WERE EXCEEDED

Station Number	Station location	Operating Period	Percent of time exceeding:		
			0.05 ppm	0.10 ppm	0.15 ppm
14	Cheverly	5/67-8/67	9	2	<1
15	Hyattsville	3/67-4/67	24	2	0
21	Alexandria	4/67-8/67	10	1	<1
33	CAMP	6/64-8/66	24	2	<1
46	Seven Corners	2/67-7/67	4	<1	0
58	N.I.H.	3/67-8/67	40	8	1
59	Suitland	2/67-7/67	1	0	0

Table 25. CUMULATIVE PERCENT FREQUENCY OF OCCURRENCE OF HOURLY AVERAGE OXIDANT CONCENTRATIONS AT CAMP STATION, 1964-66

Month	Number obs	Concentration, ppm						
		Percent of time ≥ stated value					Max. value	Arith. mean
		70	50	30	10	1		
June	1583	0.02	0.03	0.04	0.07	0.11	0.17	0.04
July	1749	0.02	0.03	0.05	0.07	0.12	0.15	0.04
August	1815	0.02	0.03	0.04	0.07	0.12	0.16	0.04

Table 26. OXIDANT DATA OBTAINED BY METROPOLITAN WASHINGTON COUNCIL OF GOVERNMENTS NETWORK

		Concentration, ppm			
				Number of observations exceeding	
June-July 1967[a]	Number obs	Max.	Arith mean	0.10 ppm	0.15 ppm
D.C. Municipal Center	36	0.11	0.05	1	0
Alexandria	49	0.13	0.04	2	0
Fairfax	33	0.15	0.05	2	0
Arlington	36	0.13	0.04	2	0
Rockville	42	0.12	0.05	2	0
Cheverly	39	0.06	0.02	0	0
Westgate	39	0.09	0.03	0	0
				Number of observations exceeding	
June, July, August 1965-66[b]				0.20 ppm	0.25 ppm
D.C. Municipal Center	118	0.53	0.12	22	8
Alexandria	121	0.33	0.08	12	6
Fairfax	24	0.36	0.15	3	2
Arlington	109	0.24	0.05	3	0
Rockville	110	0.21	0.07	1	0
Cheverly	123	0.31	0.08	13	3
Westgate	84	0.23	0.06	5	0

[a] Potassium iodide method.

[b] Phenolphthalin method.

potassium iodide method. The potassium iodide method gives data consistent with those obtained by continuous monitoring instruments. Concentrations exceeding 0.1 ppm were observed during June and July of 1967 at all stations except two. During 1965 and 1966, concentrations exceeding 0.25 ppm as measured by the phenolphthalin method were observed at four of the seven sampling sites.

Nitrogen Oxides

Nitrogen dioxide concentrations were monitored continuously at NIH and Alexandria from March to August, 1967. Cumulative percent frequency distributions of hourly average nitrogen dioxide concentrations are presented in Table 27. Atmospheric nitrogen dioxide levels were similar at these locations and ranged from <0.01 to 0.12 ppm, with an arithmetic mean of 0.02 ppm at Alexandria and NIH from <0.01 to 0.15 ppm, with an arithmetic mean of 0.03 ppm at NIH.

Monthly average nitrogen dioxide data obtained at the CAMP station from March to July, 1967 were compared with data obtained at the two suburban stations (Table 28). Monthly mean concentrations observed at the CAMP station were higher than those at the suburban stations.

To indicate seasonal fluctuation in oxides of nitrogen concentration, data obtained at the CAMP station during the months of January, April, July, and October from 1963 to 1967 were examined (Table 29). Highest nitric oxide levels occur during January and October, and lowest, during July. Data obtained for nitrogen dioxide indicates no seasonal variation. On the average, nitric oxide concentration exceeds nitrogen dioxide concentration during the months of January and October, nitrogen dioxide concentration exceeds nitric oxide concentration during the months of April and July.

Hydrocarbons

Data on hydrocarbon concentration were obtained with continuous-monitoring flame-ionization analyzers at the CAMP and NIH stations. Hourly average hydrocarbon concentrations observed from March to August, 1967 at NIH ranged from 1.0 to 7.1 ppm, with an arithmetic mean of 1.6 ppm (Table 30). Ten percent of the values exceeded 2.3 ppm, and 1 percent of the values exceeded 4.2 ppm.

Hourly data obtained at the CAMP station from 1963 to 1967 are summarized for the months of January, April, July, and October in Table 31. Arithmetic mean concentration for the months of observation varied from 2.3 to 2.9 ppm, and maximum hourly concentrations varied from 9.3 to 14.6 ppm. One percent of the values for any of the monthly periods observed were 5 ppm or higher and 10 percent of the values equaled or exceeded 3 ppm.

Table 27. CUMULATIVE PERCENT FREQUENCY OF OCCURRENCE OF HOURLY AVERAGE NITROGEN DIOXIDE CONCENTRATION

Station number	Station location	Operating period	No. obs	Concentration, ppm										
				Min. value	Percent of time ≥ stated value							Max. value	Arith mean	Std dev
					90	70	50	30	16	10	1			
21	Alexandria	3/67-8/67	1930	0.01	0.01	0.01	0.02	0.03	0.04	0.04	0.09	0.12	0.02	0.02
58	N.I.H.	2/67-8/67	2422	0.01	0.01	0.01	0.02	0.03	0.05	0.05	0.10	0.15	0.03	0.02

Table 28. MONTHLY AVERAGE NITROGEN DIOXIDE CONCENTRATION, 1967

Station number	Station location	March	April	May	June	July
33	CAMP	0.05	0.05	0.04	0.05	0.04
21	Alexandria	0.03	0.03	0.03	0.02	0.02
58	N.I.H.	0.03	0.04	0.03	0.02	0.02

Table 29. CUMULATIVE PERCENT FREQUENCY OF OCCURRENCE OF HOURLY AVERAGE NITRIC OXIDE AND NITROGEN DIOXIDE CONCENTRATIONS AT CAMP STATION

Pollutant	Month	Years of obs.	No. obs	Concentration, ppm						
				Percent of time ≥ stated value					Max. value	Arith mean
				70	50	30	10	1		
Nitric oxide	January	63-67	2399	0.02	0.03	0.06	0.13	0.38	0.88	0.06
	April	63-66	2588	0.01	0.01	0.02	0.05	0.23	0.52	0.02
	July	63-66	2285	<0.01	0.01	0.01	0.02	0.08	0.17	0.01
	October	63-66	2350	<0.01	0.03	0.06	0.18	0.37	0.63	0.07
Nitrogen dioxide	January	63-67	2807	0.02	0.03	0.04	0.06	0.10	0.23	0.04
	April	63-67	2747	0.02	0.03	0.04	0.06	0.10	0.23	0.04
	July	63-66	2528	0.02	0.03	0.04	0.05	0.08	0.17	0.03
	October	63-66	2742	0.02	0.03	0.04	0.06	0.11	0.22	0.04

Table 30. CUMULATIVE PERCENT FREQUENCY OF OCCURRENCE OF HOURLY AVERAGE HYDROCARBON CONCENTRATION AT N.I.H. STATION

Station number	Station location	Obs period	No. obs	Concentration, ppm								
				Percent of time ≥ stated value						Max. value	Arith mean	Arith std dev
				70	50	30	16	10	1			
58	N.I.H.	3/67-8/67	1803	1.3	1.5	1.7	2.0	2.4	4.3	7.1	1.6	0.8

Table 31. CUMULATIVE PERCENT FREQUENCY OF OCCURRENCE OF HOURLY AVERAGE HYDROCARBON CONCENTRATION AT CAMP STATION

Month	Years	No. obs	Concentration, ppm						
			Percent of time > stated value					Max. value	Arith mean
			70	50	30	10	1		
January	63-67	2840	2.1	2.5	2.9	3.8	6.7	14.6	2.7
April	63-67	2951	1.9	2.0	2.2	3.0	5.0	12.0	2.3
July	63-66	2862	1.9	2.1	2.9	3.9	5.0	9.3	2.5
October	63-66	1541	2.2	2.6	3.0	4.1	7.7	12.7	2.9

AIR POLLUTION EFFECTS

Information concerning the effects of air pollution on vegetation and materials was gathered in the survey area. Both indigenous vegetation and experimentally grown vegetation were examined for damage caused by air pollutants at five locations. Effects such as soiling, corrosion, and deterioration of materials were measured.

Rubber deterioration was investigated at 16 locations to define the formation and movement of photochemical pollutants.

Vegetation Effects

During the 1967 growing season, a botanist made four different inspections of some of the indigenous vegetation in the Washington, D. C., metropolitan area. Inspection tours consisted of observing vegetation at 10 to 15 locations and took about 1-1/2 days. The findings of the inspections are reported in Table 32.

Table 32. DAMAGE TO INDIGENOUS VEGETATION

Date	Location	Vegetation type	Pollutant cause	Degree of Damage
4/10/67	9th and C Street, D. C.	Tulip	SO_2	Little
4/11/67	Vernon and Colonial Avenue Alexandria, Virginia	Rose	SO_2	Trace
5/3/67	A mile southwest of Potomac River Pepco Power Plant	Pine	SO_2	Little
		Begonia	SO_2	Little
5/24/67	U. S. Naval Station	Honeysuckle	SO_2	Moderate
		Crab Apple	SO_2	Moderate
6/20/67	12th and Independence, D. C.	Buck thorn hedge	SO_2	Little
		Buckeye tree	SO_2	Little
		Petunia	PAN	Little
		Petunia	O_x	Little
6/20/67	Beltsville, Md.	Tobacco	O_3	Moderate

Experimental vegetation was cultured hydroponically in vermiculite in exposure chambers from May 2 through July 7, 1967, in Alexandria, Virginia; Washington Monument area; and the Police Park in Riverdale, Maryland. In addition, a control chamber ventilated with clean air was operated at Alexandria. The exposure chambers were ventilated with ambient air at a rate of about one air change per minute. The control chamber was ventilated with filtered air, which was passed through activated charcoal. Specimen plants were also exposed at the National Institutes of Health greenhouse in Bethesda, Maryland, during the last 6 weeks of the investigation. Tobacco W_3, pinto bean, geranium, petunia, begonia, and gladiolus (Snow princess) plants were exposed in each chamber. The pots were kept in shallow trays with Hoagland nutrient solution; distilled water was added as needed. Each week the vermiculite was flushed with distilled water, and the plants were placed in fresh nutrient solution. Exposures were arranged so that damage could be determined during the entire exposure period and during each of the 3-week increments during the exposure period. Vegetation was also examined for short-term damage each week when the plants were tended.

Table 33 summarizes the leaf damage found on the experimental vegetation. The time of occurrence of the damage is designated by periods 1, 2, 3, or 4, which correspond to the time intervals from May 2 to May 23, May 24 to June 20, June 21 to July 7, and May 2 to July 7, 1967. In Table 33 both the type and amount of damage are listed. When the type of injury is specific to a certain pollutant, it is listed according to pollutant; however, if the type is nonspecific, it is listed according to type of damage such as chlorosis. The amount of damage is listed as percentage of leaf damage or as trace (T), little (L), moderate (M), or severe (S). Severe damage means that 50 to 100 percent of the leaf tissue is damaged; moderate means that 25 to 50 percent is damaged; little means that 5 to 25 percent is damaged; and trace means that 0 to 5 percent is damaged.

Table 33. SUMMARY OF LEAF DAMAGE

Vegetation	Period	Washington Monument	Alexandria, Virginia	Riverdale, Maryland	National Institutes of Health
	1	O_3+SO_2(35%)	O_3+SO_2(50%)	O_3(25%)	-
Tobacco	2	O_3 (10%)	O_3 (10%)	O_3(25%)	O_3(20%)
	3	O_3 (10%)	O_3 (10%)	O_3(45%)	O_3(30%)
	1	PAN (T)	PAN (L)	PAN (T)	-
Pinto bean	2	PAN (S)	PAN (S)	OX & PAN (M)	PAN (M)
	3	PAN (M)	PAN (S)	OX & PAN (L)	PAN (M)
	1	none	none	none	-
Begonia	2	none	none	OX (M)	OX (L)
	3	none	none	OX (M)	OX (L)
Petunia	4	Chlorosis(L)	Chlorosis(L)	Chlorisis(M)	Chlorosis(M)
Geranium	4	Chlorosis (L)	Chlorosis(L)	Chlorosis(L)	Chlorosis(L)
					-

T - Trace (0-5%)   M - Moderate (25-50%)
L - Little (5-25%)   S - Severe (50-100%)

Table 34 lists the amount of growth suppression believed to be caused by air pollutants. The amount was determined at the end of the study period by a visual comparison of the exposed plants and the plants grown in the control chamber in Alexandria, Virginia. A suppression value of 35 percent means that the plant growth was 35 percent less than that of a similar plant grown in the Alexandria control chamber.

Table 34. PLANT GROWTH SUPPRESSION

Vegetation	Washington Monument	Alexandria, Virginia	Riverdale, Maryland	Alexandria Control
Tobacco	35	55	70	0
Pinto bean	35	40	50	0
Geranium	60	30	55	0
Petunia	40	60	70	0
Begonia	45	35	65	0
Gladiolus	0	0	0	0

Table 35 lists measurements made on tobacco at the end of the 10-week study period.

Table 35. AIR POLLUTION EFFECTS ON TOBACCO

	Washington Monument	Alexandria, Virginia	Riverdale, Maryland	Alexandria Control
Number of leaves destroyed	12	19	21	0
% of leaves destroyed	41	65	70	0
Stem cross-section area, in^2.	0.28	0.30	0.27	0.60
% suppression of root system	50	50	72	0
Root system weight, grams	350	360	220	790

Material Effects

Effects of air pollution on materials were measured at Park Services (D.C.), CAMP, Alexandria, Cheverly, and Leesburg (Loudoun Co.) in the area. The CAMP station has operated since January 1966; the others have operated since January 1967. At these locations measurements of corrosion of zinc and steel; color fading of fabric dye; and deterioration of rubber, silver, and nylon fabric.

Results from the single station operating in 1966 indicated that fabric dye fading was high at this station in 1966. This was true for dyes sensitive to nitrogen oxides. Dyes sensitive to ozone-type fading were not found to be severely affected. Silver tarnishing was found to be moderate. Corrosion and deterioration of rubber and nylon were neither unusually high nor low at this station in 1966.

Results from the first half of 1967 from all five stations confirm that dye fading caused by nitrogen oxide is high.

Rubber deterioration was measured at 16 locations (including the five effects stations) from February through August 1967. The overall average rubber cracking rate was found to be 0.19 millimeters per 7-day exposure with individual values ranging up to 0.32 millimeters per exposure period. The monthly variation in rate is shown by the monthly averages in Table 36.

Table 36. RUBBER DETERIORATION IN STUDY AREA

Month	Average Rate mm/wk
February	0.08
March	0.19
April	0.21
May	0.21
June	0.17
July	0.18
August	0.17

The geographical distribution of the rubber deterioration and the average rates for the study period are presented in Figure 15.

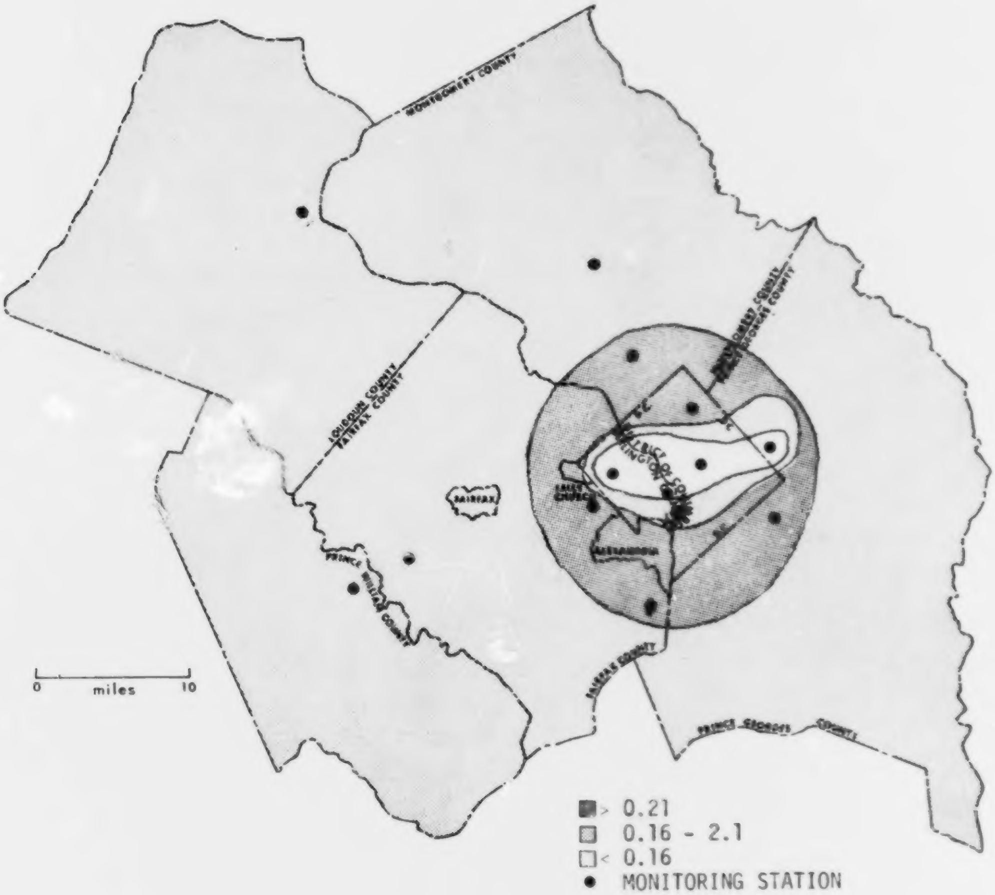
MONTGOMERY COUNTY
MONTGOMERY COUNTY
PRINCE GEORGES COUNTY
LOUDOUN COUNTY
FAIRFAX COUNTY
FAIRFAX
FALLS CHURCH
DISTRICT OF COLUMBIA
ARLINGTON
ALEXANDRIA
PRINCE WILLIAM COUNTY
FAIRFAX COUNTY
PRINCE GEORGES COUNTY
0 miles 10
■ > 0.21
▨ 0.16 - 2.1
☐ < 0.16
● MONITORING STATION

Figure 15. Geographical distribution of rubber deterioration rate - average crack depth per 7 days (in mm).

EMISSION INVENTORY

An inventory of pollutant emissions from the various sources in the metropolitan Washington, D. C., area was completed from data for the years 1965 and 1966. The pollutants inventoried were sulfur oxides (reported as SO_2), nitrogen oxides (reported as NO_2), carbon monoxide, particulate, and hydrocarbons (reported as methane). The surveyed emissions were from stationary fuel combustion sources, process losses, refuse burning, motor vehicles, railroads, and aircraft.

The air contaminants discharged to the atomosphere annually from sources in the study area are listed in Tables 37 through 41 by source category. These figures show that 247,000 tons of sulfur oxides, 135,000 tons of nitrogen oxides, 1,260,000 tons of carbon monoxide, 35,000 tons of particulate, and 310,000 tons of hydrocarbons - a total of almost 2,000,000 tons of these five pollutants - are emitted annually in the metropolitan Washington, D. C., area. The major portion of these pollutants is generated in the District of Columbia and its fringe areas, which include Arlington County, the city of Alexandria, and portions of Montgomery, Prince Georges, and Fairfax Counties. Overall, the District of Columbia contributes 28 percent of the total pollutants, and the portions of Maryland and Virginia within the study area generate 40 percent and 32 percent, respectively, of the total. The contributions of the three major areas contributing to the pollution problem are shown in Table 42.

Oxides of sulfur (97 percent of which is SO_2, the remainder being SO_3 or sulfuric acid mist) emitted in the study area are mainly generated by the combustion of sulfur-bearing fuel at stationary sources. As shown in Figure 16, these fuels contribute 98 percent of the sulfur oxides. The other 2 percent of the sulfur oxides is emitted by refuse burning and mobile sources.

The sulfur oxides from fuel combustion reflect fuel quantities and sulfur contents. Average sulfur contents (Appendix C) were used for area-wide fuel sources. At any surveyed source, the reported fuel sulfur content was used for emission calculations.

Oxides of nitrogen emissions in the Washington, D. C., area are generated mainly by the combustion of fuel in stationary and mobile sources. As is shown in Figure 17, the burning of fuel at stationary sources contributes 60 percent of the nitrogen oxides, while mobile sources generate 39 percent. The other 1 percent of the nitrogen oxides is emitted by refuse burning.

The oxides of nitrogen emissions from heating fuels, gasoline and diesel oil reflect fuel quantities, nitrogen content, and combustion conditions.

Carbon monoxide emissions for the study area can nearly all be attributed to the combustion of gasoline and diesel fuel by motor vehicles. As is shown in Figure 18,

Table 37. SULFUR OXIDE EMISSIONS[a] IN WASHINGTON, D.C., METROPOLITAN AREA, 1965-1966
(tons/year)

County or city	Residential fuel						Commercial and Governmental fuel[b]					
	Coal		Fuel oil		Natural gas	Total	Coal		Fuel oil		Natural gas	Total
	Anthracite	Bituminous	Distillate	Residual			Anthracite	Bituminous	Distillate	Residual		
District of Columbia	294	-	1,356	8,719	3	10,372	66	9,397	1,368	20,203	Neg	31,034
Montgomery Co.	158	-	678	2,759	3	3,598	-	139	263	4,559	Neg	4,961
Prince Georges Co.	190	-	969	3,188	2	4,349	-	1,434	286	5,396	Neg	7,116
Maryland subtotal	348	-	1,647	5,947	5	7,947	-	1,573	549	9,955	Neg	12,077
Arlington Co.	6	31	293	3,255	1	3,586	-	793	193	2,798	Neg	3,784
Fairfax Co.	11	-	595	1,017	2	1,625	-	560	291	4,446	Neg	5,297
Loudoun Co.	1	-	161	49	-	211	-	10	20	171	Neg	201
Prince William Co.	2	-	158	91	Neg	251	-	-	101	184	Neg	285
Alexandria City	71	12	300	1,653	1	2,037	3	57	104	1,617	Neg	1,781
Fairfax City	1	-	51	65	Neg	117	-	10	22	72	Neg	104
Falls Church City	2	-	48	15	Neg	65	-	10	4	87	Neg	101
Virginia subtotal	94	43	1,606	6,145	4	7,892	3	1,440	735	9,375	Neg	11,553
Area total	736	43	4,609	20,811	12	26,211	69	12,410	2,652	39,533	Neg	54,664

[a] As SO_2.

[b] Includes emissions from Federal sources.

Table 37. (continued) SULFUR OXIDE EMISSIONS[a] IN WASHINGTON, D.C., METROPOLITAN AREA, 1965-1966
(tons/year)

County or city	Industrial fuel					Power plants			
	Coal, bituminous	Fuel oil		Natural gas	Total	Coal, bituminous	Fuel oil		Total
		Distillate	Residual				Distillate	Residual	
District of Columbia	38	13	1611	Neg.	1662	15,554	15	142	15,711
Montgomery Co.	10	44	1103	Neg.	1157	58,532	23	-	58,555
Prince Georges Co.	10	54	1446	Neg.	1510	49,825	41	-	49,866
Maryland subtotal	20	98	2549	Neg.	2667	108,357	64	-	108,421
Arlington Co.	10	5	128	Neg.	143	-	-	-	-
Fairfax Co.	67	27	615	Neg.	709	-	-	-	-
Loudoun Co.	-	1	29	Neg.	30	-	-	-	-
Prince William Co.	-	1	33	Neg.	34	15,123	-	-	15,123
Alexandria City	10	18	320	Neg.	348	16,456	38	-	16,494
Fairfax City	-	N	1	N	1	-	-	-	-
Falls Church City	-	1	21	N	22	-	-	-	-
Virginia subtotal	87	53	1147	Neg.	1287	31,579	38	-	31,617
Area total	145	164	5307	Neg.	5616	155,490	117	142	155,749

Table 37. (continued) SULFUR OXIDE EMISSIONS[a] IN WASHINGTON, D.C., METROPOLITAN AREA, 1965-1966
(tons/year)

County or city	Total fuel[b]						Motor vehicles			Railroads	Aircraft[b]
	Coal		Fuel oil		Natural gas	Total	Gasoline	Diesel	Total		
	Anthracite	Bituminous	Distillate	Residual							
District of Columbia	360	24,989	2752	30,675	3	58,779	960	264	1224	9	-
Montgomery Co.	158	58,681	1008	8,421	3	68,271	600	83	683	1	-
Prince Georges Co.	190	51,269	1350	10,030	2	62,841	680	92	772	4	Neg.
Maryland subtotal	348	109,950	2358	18,451	5	131,112	1280	175	1455	5	Neg.
Arlington Co.	6	834	491	6,181	1	7,513	271	37	308	2	Neg.
Fairfax Co.	11	627	913	6,078	2	7,631	424	59	483	2	-
Loudoun Co.	1	10	182	249	Neg.	442	54	7	61	1	Neg.
Prince William Co.	2	15,123	260	308	Neg.	15,693	120	18	138	1	-
Alexandria City	74	16,535	460	3,590	1	20,660	184	26	210	3	-
Fairfax City	1	10	73	138	Neg.	222	68	9	77	-	-
Falls Church City	2	10	53	123	Neg.	188	27	4	31	Neg.	-
Virginia subtotal	97	33,149	2432	16,667	4	52,349	1148	160	1308	9	Neg.
Area total	805	168,088	7542	65,793	12	242,240	3388	599	3987	23	Neg.

Table 37. (continued) SULFUR OXIDE EMISSIONS[a] IN WASHINGTON, D.C., METROPOLITAN AREA 1965-1966
(tons/year)

County or city	Process	Refuse[b] disposal	Grand[b] total	Federal Government sources								
				Fuel combustion						Refuse	Aircraft	Total Federal
				Coal		Fuel oil		Natural gas	Total fuel			
				Anthracite	Bituminous	Distillate	Residual					
District of Columbia	-	400	60,412	-	8,610	10	7,420	Neg.	16,040	70	-	16,110
Montgomery Co.	-	205	69,160	-	-	5	2,470	Neg.	2,475	10	-	2,485
Prince Georges Co.	-	39	63,656	-	630	20	1,950	Neg.	2,600	-	Neg.	2,600
Maryland subtotal	-	244	132,816	-	630	25	4,420	Neg.	5,075	10	Neg.	5,085
Arlington Co.	-	94	7,917	-	750	20	970	Neg.	1,740	Neg.	Neg.	1,740
Fairfax Co.	-	33	8,149	-	120	90	1,220	Neg.	1,430	-	-	1,430
Loudoun Co.	-	8	512	-	-	-	-	Neg.	Neg.	-	Neg.	Neg.
Prince William Co.	-	18	15,850	-	-	-	130	Neg.	130	-	-	130
Alexandria City	-	67	20,940	-	-	-	280	Neg.	280	Neg.	-	280
Fairfax City	-	2	301	-	-	-	-	-	-	-	-	-
Falls Church City	-	1	220	-	-	-	-	-	-	-	-	-
Virginia subtotal	-	223	53,889	-	870	110	2,600	Neg.	3,580	Neg.	Neg.	3,580
Area total	-	867	247,117	-	10,110	145	14,440	Neg.	24,695	80	Neg.	24,775

Table 38. OXIDES OF NITROGEN EMISSIONS[a] IN WASHINGTON, D.C., METROPOLITAN AREA, 1965-1966
(tons/year)

County or city	Residential Fuel					
	Coal		Fuel oil		Natural gas	Total
	Anthracite	Bituminous	Distillate	Residual		
District of Columbia	107	-	2,032	1,546	922	4,607
Montgomery Co.	58	-	1,012	489	808	2,367
Prince Georges Co.	272	-	1,453	565	665	2,955
Maryland subtotal	330	-	2,465	1,054	1,473	5,322
Arlington Co.	2	7	440	577	240	1,266
Fairfax Co.	4	-	892	180	545	1,621
Loudoun Co.	Neg.	-	242	9	11	262
Prince William Co.	1	-	237	29	80	347
Alexandria City	17	3	450	293	147	910
Fairfax City	1	-	76	12	24	113
Falls Church City	1	-	72	3	19	95
Virginia subtotal	26	10	2,409	1,103	1,066	4,614
Area total	463	10	6,906	3,703	3,461	14,543

[a] As NO_2.

[b] Includes emissions from Federal sources.

Table 38 (Continued). OXIDES OF NITROGEN EMISSIONS[a] IN WASHINGTON, D.C., METROPOLITAN AREA, 1965-1966
(tons/year)

County or city	Commercial and Governmental fuels[b]					
	Coal		Fuel oil		Natural gas	Total
	Anthracite	Bituminous	Distillate	Residual		
District of Columbia	24	2,935	2,055	3,457	344	8,815
Montgomery Co.	-	30	397	1,247	122	1,796
Prince Georges Co.	-	503	431	1,102	147	2,183
Maryland subtotal	-	533	828	2,349	269	3,979
Arlington Co.	-	571	284	597	84	1,536
Fairfax Co.	-	165	426	978	67	1,636
Loudoun Co.	-	2	30	30	2	64
Prince William Co.	-	-	152	33	44	229
Alexandria City	1	52	156	318	51	578
Fairfax City	-	2	33	13	10	58
Falls Church City	-	2	5	15	8	30
Virginia subtotal	1	794	1,086	1,984	266	4,131
Area total	25	4,262	3,969	7,790	879	16,925

Table 38. OXIDES OF NITROGEN EMISSIONS[a] IN WASHINGTON, D.C., METROPOLITAN AREA, 1965-1966
(tons/year)

County or city	Industrial Fuel					Power Plant			
	Coal, bituminous	Fuel oil		Natural gas	Total	Coal, bituminous	Fuel oil		Total
		Distillate	Residual				Distillate	Residual	
District of Columbia	20	20	286	156	482	4,940	32	37	5,009
Montgomery Co.	5	29	196	50	280	13,940	51	-	13,991
Prince Georges Co.	5	36	260	68	369	13,047	89	-	13,136
Maryland subtotal	10	65	456	118	649	26,987	140	-	27,127
Arlington Co.	5	7	22	28	62	-	-	-	-
Fairfax Co.	14	26	108	33	181	-	-	-	-
Loudoun Co.	-	1	5	1	7	-	-	-	-
Prince William Co.	-	2	6	4	12	8,240	-	-	8,240
Alexandria City	5	15	65	24	109	7,946	82	-	8,028
Fairfax City	-	Neg.	Neg.	5	5	-	-	-	-
Falls Church City	-	1	4	4	9	-	-	-	-
Virginia subtotal	24	52	210	99	385	16,186	82	-	16,268
Area total	54	137	952	373	1,516	48,113	254	37	48,404

[a] As NO_2.

[b] Includes emissions from Federal sources.

Table 38 (Continued). OXIDES OF NITROGEN EMISSIONS[a] IN WASHINGTON, D.C., METROPOLITAN AREA, 1965-1966
(tons/year)

County or city	Fuel total[b]						Motor vehicles		
	Coal		Fuel oil		Natural gas	Total			
	Anthracite	Bituminous	Distillate	Residual			Gasoline	Diesel	Total
District of Columbia	131	7,895	4,139	5,326	1,422	18,913	13,593	1,473	15,066
Montgomery Co.	58	13,975	1,489	1,932	980	18,434	8,551	461	9,012
Prince Georges Co.	272	13,555	2,009	1,927	880	18,643	9,688	511	10,199
Maryland subtotal	330	27,530	3,498	3,859	1,860	37,077	18,239	972	19,211
Arlington Co.	2	583	731	1,196	352	2,864	3,861	208	4,069
Fairfax Co.	4	179	1,344	1,266	645	3,438	6,043	326	6,369
Loudoun Co.	Neg.	2	273	44	14	333	763	41	804
Prince William Co.	1	8,240	391	68	128	8,828	1,710	92	1,802
Alexandria City	18	8,006	703	676	222	9,625	2,628	142	2,770
Fairfax City	1	2	109	25	39	176	969	52	1,021
Falls Church City	1	2	78	22	31	134	382	21	403
Virginia subtotal	27	17,014	3,629	3,297	1,431	25,398	16,356	882	17,238
Area total	488	52,439	11,266	12,482	4,713	81,388	48,188	3,327	51,515

Table 38 (Continued). OXIDES OF NITROGEN EMISSIONS[a] IN WASHINGTON, D.C., METROPOLITAN AREA, 1965-1966
(tons/year)

						Federal Government sources								
						Fuel combustion								
						Coal		Fuel oil		Natural gas	Total fuel	Refuse	Aircraft	Total Federal
County or city	Railroads	Aircraft[b]	Process	Refuse[b]	Grand Total[b]	Anthracite	Bituminous	Distillate	Residual					
District of Columbia	70	-	-	423	34,472	-	3,010	10	1,440	60	4,520	40	-	4,560
Montgomery Co.	8	-	-	233	27,687	-	-	10	950	10	970	10	-	980
Prince Georges Co.	21	440	-	34	29,337	-	220	90	410	10	730	-	440	1,170
Maryland Subtotal	29	440	-	267	57,024	-	220	100	1,360	20	1,700	10	440	2,150
Arlington Co.	13	435	-	93	7,474	-	560	30	250	10	850	10	435	1,295
Fairfax Co.	11		-	51	9,869	-	70	170	310	10	560	-	-	560
Loudoun Co.	4	145	-	10	1,296	-	-	-	-	10	10	-	145	155
Prince William Co.	6		-	13	10,649	-	-	-	20	20	40	-	-	40
Alexandria City	14		-	74	12,483	-	-	-	60	10	70	Neg.	-	70
Fairfax City	-		-	3	1,200	-	-	-	-	-	-	-	-	-
Falls Church City	1		-	2	540	-	-	-	-	-	-	-	-	-
Virginia Subtotal	49	580	-	246	43,511	-	630	200	640	60	1,530	10	580	2,120
Area total	148	1,020	-	936	135,007	-	3,860	310	3,440	140	7,750	60	1,020	8,830

Table 39. CARBON MONOXIDE EMISSIONS IN WASHINGTON, D.C. METROPOLITAN AREA, 1965-1966
(tons/year)

	Residential fuel						Commercial and Governmental fuel[a]					
	Coal		Fuel oil		Natural gas	Total	Coal		Fuel oil		Natural gas	Total
County or city	Anthracite	Bituminous	Distillate	Residual			Anthracite	Bituminous	Distillate	Residual		
District of Columbia	668	-	56	43	3	770	149	832	56	96	Neg.	1,133
Montgomery Co.	358	-	32	14	3	407	-	188	11	29	Neg.	228
Prince Georges Co.	433	-	40	16	2	491	-	168	12	24	Neg.	204
Maryland subtotal	791	-	72	30	5	898	-	356	23	53	Neg.	432
Arlington Co.	13	45	12	22	1	93	-	147	8	11	Neg.	166
Fairfax Co.	25	-	25	5	2	57	-	634	15	20	Neg.	669
Loudoun Co.	2	-	7	Neg.	Neg.	9	-	13	1	1	Neg.	15
Prince William Co.	5	-	7	1	Neg.	13	-	-	4	1	Neg.	5
Alexandria City	106	18	13	9	Neg.	146	5	78	3	6	Neg.	92
Fairfax City	3	-	2	Neg.	Neg.	5	-	13	1	1	Neg.	15
Falls Church City	3	-	2	Neg.	Neg.	5	-	13	Neg.	Neg.	Neg.	13
Virginia subtotal	157	63	68	37	3	328	5	898	32	40	Neg.	975
Area total	1,616	63	196	110	11	1,996	154	2,086	111	189	Neg.	2,540

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[a] Includes emissions from Federal sources.

Table 39. (continued) CARBON MONOXIDE EMISSIONS IN WASHINGTON, D.C. METROPOLITAN AREA 1965-1966
(tons/year)

County or city	Industrial fuel					Power plants			
	Coal, bituminous	Fuel oil		Natural gas	Total	Coal, bituminous	Fuel oil		Total
		Distillate	Residual				Distillate	Residual	
District of Columbia	4	1	8	Neg.	13	123	Neg.	Neg.	123
Montgomery Co.	1	1	5	Neg.	7	348	Neg.	-	348
Prince Georges Co.	1	1	7	Neg.	9	326	Neg.	-	326
Maryland subtotal	2	2	12	Neg.	16	674	Neg.	Neg.	674
Arlington Co.	1	Neg.	Neg.	Neg.	1	-	-	-	-
Fairfax Co.	7	1	3	Neg.	11	-	-	-	-
Loudoun Co.	-	Neg.	Neg.	Neg.	Neg.	-	-	-	-
Prince William Co.	-	Neg.	Neg.	Neg.	Neg.	206	-	-	206
Alexandria City	1	Neg.	1	Neg.	2	199	Neg.	-	199
Fairfax City	-	Neg.	Neg.	Neg.	Neg.	-	-	-	-
Falls Church City	-	Neg.	Neg.	Neg.	Neg.	-	-	-	-
Virginia subtotal	9	1	4	Neg.	14	405	Neg.	Neg.	405
Area total	15	4	24	Neg.	43	1,202	Neg.	Neg.	1,202

[a] Includes emissions from Federal sources

Table 39. (continued) CARBON MONOXIDE EMISSIONS IN WASHINGTON, D.C. METROPOLITAN AREA 1965-1966
(tons/year)

County or city	Total fuel[a]						Motor vehicles			Railroads	Aircraft[a]	Process	Refuse[a] disposal
	Coal		Fuel oil		Natural gas	Total	Gasoline	Diesel	Total				
	Anthracite	Bituminous	Distillate	Residual									
District of Columbia	817	959	113	147	3	2,039	349,249	401	349,650	14	-	-	5,371
Montgomery Co.	358	537	44	48	3	990	218,400	125	218,525	2	-	-	329
Prince Georges Co.	433	495	53	47	2	1,030	247,350	138	247,488	5	4,930	-	1,172
Maryland subtotal	791	1,032	97	95	5	2,020	465,750	263	466,013	7	4,930	-	1,501
Arlington Co.	13	193	20	33	1	260	98,648	56	98,704	4	3,400	-	596
Fairfax Co.	25	641	41	28	2	737	154,229	88	154,317	3	-	-	614
Loudoun Co.	2	13	8	1	Neg.	24	19,498	11	19,509	1	1,075	-	80
Prince William Co.	5	206	11	2	Neg.	224	43,652	25	43,677	2	-	-	738
Alexandria City	111	296	16	16	Neg.	439	67,075	38	67,113	4	-	-	997
Fairfax City	3	13	3	1	Neg.	20	24,735	14	24,749	-	-	-	43
Falls Church City	3	13	2	Neg.	Neg.	18	9,749	6	9,755	-	-	-	28
Virginia subtotal	162	1,375	101	81	3	1,722	417,586	238	417,824	14	4,475	-	3,096
Area total	1,770	3,366	311	323	11	5,781	1,232,585	902	1,233,487	35	9,405	-	9,968

[a] Includes emissions from Federal sources

Table 39. (continued) CARBON MONOXIDE EMISSIONS IN WASHINGTON, D.C. METROPOLITAN AREA 1965-1966
(tons/year)

County or city	Grand total[a]	Federal Government sources								
		Fuel combustion						Refuse	Aircraft[a]	Total Federal
		Coal		Fuel oil		Natural gas	Total fuel			
		Anthracite	Bituminous	Distillate	Residual					
District of Columbia	357,074	-	600	Neg.	30	Neg.	630	4,970	-	5,600
Mongtomery Co.	219,846	-	-	Neg.	10	Neg.	10	160	-	170
Prince Georges Co.	254,625	-	30	Neg.	10	Neg.	40	-	4,930	4,970
Maryland subtotal	474,471	-	30	Neg.	20	Neg.	50	160	4,930	5,140
Arlington Co.	102,964	-	80	Neg.	Neg.	Neg.	80	390	3.400	3,870
Fairfax Co.	155,671	-	10	-	10	Neg.	20	-	-	20
Loudoun Co.	20,689	-	-	-	-	Neg.	Neg.	-	1,075	1,075
Prince William Co.	44,641	-	-	Neg.	Neg.	Neg.	Neg.	-	-	Neg.
Alexandria City	68,553	-	-	-	Neg.	Neg.	Neg.	40	-	40
Fairfax City	24,812	-	-	-	-	-	-	-	-	-
Falls Church City	9,801	-	-	-	-	-	-	-	-	-
Virginia subtotal	427,131	-	90	Neg.	10	Neg.	100	430	4,425	5,005
Area total	1,258,676	-	720	Neg.	60	Neg.	780	5,560	9,405	15,745

[a] Includes emissions from Federal sources.

TABLE 40. PARTICULATE EMISSIONS IN WASHINGTON, D. C., METROPOLITAN AREA, 1965-1966

(tons/year)

County or city	Residential fuel						Commercial and Governmental fuel[a]					
	Coal		Fuel oil		Natural gas	Total	Coal		Fuel oil		Natural gas	Total
	Anthracite	Bituminous	Distillate	Residual			Anthracite	Bituminous	Distillate	Residual		
District of Columbia	268	-	339	258	159	1024	149	1086	342	575	59	2211
Montgomery County	143	-	170	82	139	534	-	135	66	140	19	360
Prince Georges County	173	-	242	94	111	620	-	1589	72	160	25	1846
Maryland subtotal	316	-	412	176	250	1154	-	1724	138	300	44	2206
Arlington County	5	36	73	96	41	251	-	294	47	77	11	429
Fairfax County	10	-	149	30	94	283	-	553	71	141	12	777
Loudoun County	1	-	40	2	2	45	-	9	5	5	Neg.	19
Prince William County	2	-	40	5	14	61	-	-	25	5	8	38
Alexandria City	81	14	75	116	25	311	4	54	26	45	9	138
Fairfax City	1	-	14	2	4	21	-	9	6	2	2	19
Falls Church City	1	-	12	Neg.	3	16	-	9	1	3	1	14
Virginia subtotal	101	50	403	251	183	988	4	928	181	278	43	1434
Area total	685	50	1154	685	592	3166	153	3738	661	1153	146	5851

[a] Includes emissions from Federal sources.

Table 40 (continued). PARTICULATE EMISSIONS IN WASHINGTON, D. C., METROPOLITAN AREA 1965-1966 (tons/year)

County or city	Industrial fuel					Power plants			
	Coal, bituminous	Fuel oil		Natural gas	Total	Coal, bituminous	Fuel oil		Total
		Distillate	Residual				Distillate	Residual	
District of Columbia	36	3	48	13	100	1179	2	3	1184
Montgomery County	9	5	33	4	51	4155	4	-	4159
Prince Georges County	9	6	44	6	65	2246	7	-	2253
Maryland subtotal	18	11	77	10	116	6401	11	-	6412
Arlington County	9	2	4	2	17	-	-	-	-
Fairfax County	63	4	18	3	88	-	-	-	-
Loudoun County	-	Neg.	1	Neg.	1	-	-	-	-
Prince William County	-	Neg.	1	4	5	1685	-	-	1685
Alexandria City	9	3	9	2	23	625	6	-	631
Fairfax City	-	Neg.	Neg.	Neg.	Neg.	-	-	-	-
Falls Church City	-	Neg.	1	Neg.	1	-	-	-	-
Virginia subtotal	81	9	34	11	135	2310	6	-	2316
Area total	135	23	159	34	351	9890	19	3	9912

[a] Includes emissions from Federal sources

Table 40 (continued). PARTICULATE EMISSIONS IN WASHINGTON, D.C., METROPOLITAN AREA, 1965-1966

(tons/year)

County or city	Total fuel						Motor vehicles			Railroads	Aircraft[a]
	Coal		Fuel oil		Natural gas	Total					
	Anthracite	Bituminous	Distillate	Residual			Gasoline	Diesel	Total		
District of Columbia	417	2301	686	884	231	4519	1200	727	1927	26	-
Montgomery County	143	4299	245	255	162	5104	750	228	978	4	-
Prince Georges County	173	3844	327	298	142	4784	850	253	1103	102	145
Maryland subtotal	316	8143	572	553	304	9888	1600	481	2081	106	145
Arlington County	5	339	122	177	54	697	339	103	442	7	190
Fairfax County	10	616	224	189	109	1148	325	162	487	5	-
Loudoun County	1	9	45	8	2	65	67	21	88	2	75
Prince William County	2	1685	65	11	26	1789	150	46	196	3	-
Alexandria City	85	702	110	170	36	1103	231	71	302	7	-
Fairfax County	1	9	20	4	6	40	85	26	111	-	-
Falls Church City	1	9	13	4	4	31	34	10	44	1	-
Virginia subtotal	105	3369	599	563	237	4873	1231	439	1670	25	265
Area total	838	13813	1857	2000	772	19280	4031	1647	5678	157	410

[a] Includes emissions from Federal sources

Table 40. (continued). PARTICULATE EMISSIONS IN WASHINGTON, D. C., METROPOLITAN AREA, 1965-1966
(tons/year)

County or city	Process	Refuse[a]	Grand total	Federal Government sources								
				Fuel combustion						Refuse	Aircraft	Federal total
				Coal		Fuel oil		Natural gas	Total fuel			
				Anthracite	Bituminous	Distillate	Residual					
District of Columbia	151	4506	11,129	-	930	Neg.	220	10	1160	2730	-	3890
Montgomery County	45	400	6,531	-	-	Neg.	80	Neg.	80	60	-	140
Prince Georges County	734	879	7,747	-	350	10	60	Neg.	420	-	145	565
Maryland subtotal	779	1279	14,278	-	350	10	140	Neg.	500	60	145	705
Arlington County	18	529	1,883	-	250	10	30	Neg.	290	70	190	550
Fairfax County	31	583		-	120	30	30	Neg.	180	-	-	180
Loudoun County	-	97	327	-	-	-	-	Neg.	Neg.	-	75	75
Prince William County	1	466	2,455	-	-	-	10	Neg.	10	-	-	10
Alexandria City	121	631	2,164	-	-	-	10	-	10	40	-	50
Fairfax City	8	38	197	-	-	-	-	-	-	-	-	-
Falls Church City	1	26	103	-	-	-	-	-	-	-	-	-
Virginia subtotal	180	2370	9,383	-	370	40	80	Neg.	490	110	265	865
Area total	1110	8155	34,790	-	1650	50	440	10	2150	2900	410	5460

[a] Includes emissions from Federal sources

Table 41. HYDROCARBON EMISSIONS[a] IN WASHINGTON, D. C., METROPOLITAN AREA, 1965-1966
(tons/year)

County or city	Residential fuel						Commercial and Government fuel[b]					
	Coal		Fuel oil		Natural gas	Total	Coal		Fuel oil		Natural gas	Total
	Anthracite	Bituminous	Distillate	Residual			Anthracite	Bituminous	Distillate	Residual		
District of Columbia	134	-	56	64	Neg.	254	30	160	57	144	Neg.	1840
Montgomery Co.	72	-	28	20	Neg.	120	-	38	11	43	Neg.	92
Prince Georges Co.	87	-	40	17	Neg.	144	-	267	13	38	Neg.	318
Maryland subtotal	159		68	37	Neg.	264	-	305	24	81	Neg.	410
Arlington Co.	3		12	6	Neg.	30	-	293	8	22	Neg.	323
Fairfax Co.	5	-	25	14	Neg.	44	-	157	11	30	Neg.	198
Loudoun Co.	Neg.	-	7	Neg.	Neg.	7	-	3	1	1	Neg.	5
Prince William Co.	1	-	7	1	Neg.	9	-	-	4	1	Neg.	5
Alexandria City	21	4	12	12	Neg.	49	1	16	4	12	Neg.	33
Fairfax City	1	-	2	Neg.	Neg.	3	-	3	1	1	Neg.	5
Falls Church City	1	-	2	1	Neg.	4	Neg.	3	Neg.	1	Neg.	4
Virginia subtotal	32	13	67	34	Neg.	146	1	475	29	68	Neg.	573
Area totals	325	13	191	135	Neg.	664	31	2389	110	293	Neg.	2823

[a] As methane.

[b] Includes emissions from Federal sources.

Table 41 (continued). HYDROCARBON EMISSIONS[a] IN WASHINGTON, D. C., METROPOLITAN AREA, 1965-1966

County or city	Industrial fuel					Power plants			
	Coal, bituminous	Fuel oil		Natural gas	Total	Coal, bituminous	Fuel oil		Total
		Distillate	Residual				Distillate	Residual	
District of Columbia	1	1	12	Neg.	14	49	Neg.	1	50
Montgomery Co.	Neg.	1	8	Neg.	9	139	2	-	141
Prince Georges Co.	Neg.	1	11	Neg.	12	131	3		134
Maryland subtotal	Neg.	3	19	Neg.	21	270	5	-	275
Arlington Co.	Neg.	Neg.	1	Neg.	1	-	-	-	-
Fairfax Co.	2	1	4	Neg.	7	-	-	-	-
Loudoun Co.	-	Neg.	Neg.	Neg.	-	-	-	-	-
Prince William Co.	-	Neg.	Neg.	Neg.	-	82	-	-	82
Alexandria City	Neg.	Neg.	2	Neg.	2	79	3	-	82
Fairfax City	-	Neg.	Neg.	Neg.	-	-	-	-	-
Falls Church City	-	Neg.	Neg.	Neg.	-	-	-	-	-
Virginia subtotal	2	1	7	Neg.	10	161	3	-	164
Area totals	3	4	38	Neg.	45	480	8	1	489

[a] As methane.

Table 41 (continued). HYDROCARBON EMISSIONS[a] IN WASHINGTON, D. C., METROPOLITAN AREA, 1965-1966
(tons/year)

County or city	Total fuel[b]						Motor vehicles			Gasoline handling and evaporation	Railroads	Aircraft[b]
	Coal		Fuel oil		Natural gas	Total	Gasoline	Diesel	Total			
	Anthracite	Bituminous	Distillate	Residual								
District of Columbia	164	1,659	114	221	Neg.	2,158	62,829	1,189	64,018	14,	42	-
Montgomery Co.	72	177	42	71	Neg.	362	39,300	374	39,674	8,955	7	-
Prince Georges Co.	87	398	57	66	Neg.	608	44,540	414	44,954	10,149	17	1.390
Maryland subtotal	159	575	99	137	Neg.	970	83,840	788	84,628	19,104	24	1,390
Arlington Co.	3	302	20	29	Neg.	354	17,764	168	17,932	4,047	11	1,065
Fairfax Co.	5	159	37	48	Neg.	249	27,772	265	28,037	6,328	9	-
Loudoun Co.	Neg.	3	8	1	Neg.	12	3,511	33	3,544	800	4	435
Prince William Co.	1	82	11	2	Neg.	96	7,860	75	7,935	1,791	5	-
Alexandria City	22	99		26	Neg.	166	12,078	115	12,193	2,	12	-
Fairfax City	1	3	3	1	Neg.	8	4,454	42	4,496	1,015	-	-
Falls Church City	1	3	2	2	Neg.	8	1,755	17	1,772	400	1	-
Virginia subtotal	33	651	100	109	Neg.	893	75,194	715	75,909	17,133	42	1,500
Area totals	356	2,885	313	467	Neg.	4,021	221,863	2,692	224,555	50,553	108	2,890

[a] As methane.

[b] Includes emissions from Federal sources.

Table 41 (continued). HYDROCARBON EMISSIONS[a] IN WASHINGTON, D. C., METROPOLITAN AREA, 1965-1966
(tons/year)

						Federal Government sources									
	Process emissions					Fuel combustion									
						Coal		Fuel oil							
County or city	Dry cleaning	Solvent operations	Total	Refuse burning	Grand total	Anthracite	Bituminous	Distillate	Residual	Natural gas	Total fuel	Refuse	Aircraft	Solvent operations	Total Federal
District of Columbia	1,539	2,291	3,830	5,130	89,494	-	90	Neg.	30	Neg.	120	4,740	-	475	5,335
Montgomery Co.	868	1,024	1,892	1,009	51,899	-	-	Neg.	20	Neg.	20	230	-	-	250
Prince Georges Co.	1,060	1,251	2,311	3,791	63,220	-	10	Neg.	10	Neg.	20	-	1,390	-	1,410
Maryland subtotal	1,928	2,275	4,203	4,800	115,119	-	10	Neg.	30	Neg.	40	230	1,390	-	1,660
Arlington Co.	329	388	717	300	24,426	-	10	Neg.	Neg.	Neg.	10	90	1,065	-	1,165
Fairfax Co.	665	785	1,450	3,302	39,375	-	30	Neg.	Neg.	Neg.	30	-	-	-	30
Loudoun Co.	63	74	137	1,001	5,933	-	-	-	-	Neg.	Neg.	-	435	-	435
Prince William Co.	152	179	331	1,448	11,606	-	-	Neg.	Neg.	Neg.	Neg.	-	-	-	Neg.
Alexandria City	219	258	477	500	16,100	-	-	-	Neg.	Neg.	Neg.	50	--	-	50
Fairfax City	37	44	81	150	5,750	-	-	-	-	-	-	-	-	-	-
Falls Church City	24	28	52	103	2,336	-	-	-	-	-	-	-	-	-	-
Virginia subtotal	1,489	1,756	3,245	6,804	105,526	-	40	Neg.	Neg.	Neg.	40	140	1,500	-	1,680
Area totals	4,956	6,322	11,278	16,734	310,039	-	140	Neg.	60	Neg.	200	5,110	2,890	475	8,675

[a] As methane.

[b] Includes emissions from Federal sources.

Table 42. CONTRIBUTIONS OF MAJOR SUBDIVISIONS OF STUDY AREA TO POLLUTANT EMISSIONS, 1965-1966

Area	Fraction contributed, %					
	SO_x	NO_x	CO	Part.	HC	Total
District of Columbia	24	26	28	32	29	28
Maryland	54	42	38	41	37	40
Virginia	22	32	34	27	34	32
Total pollutants, tons/year	247,117	135,007	1,258,676	34,790	310,039	1,985,672

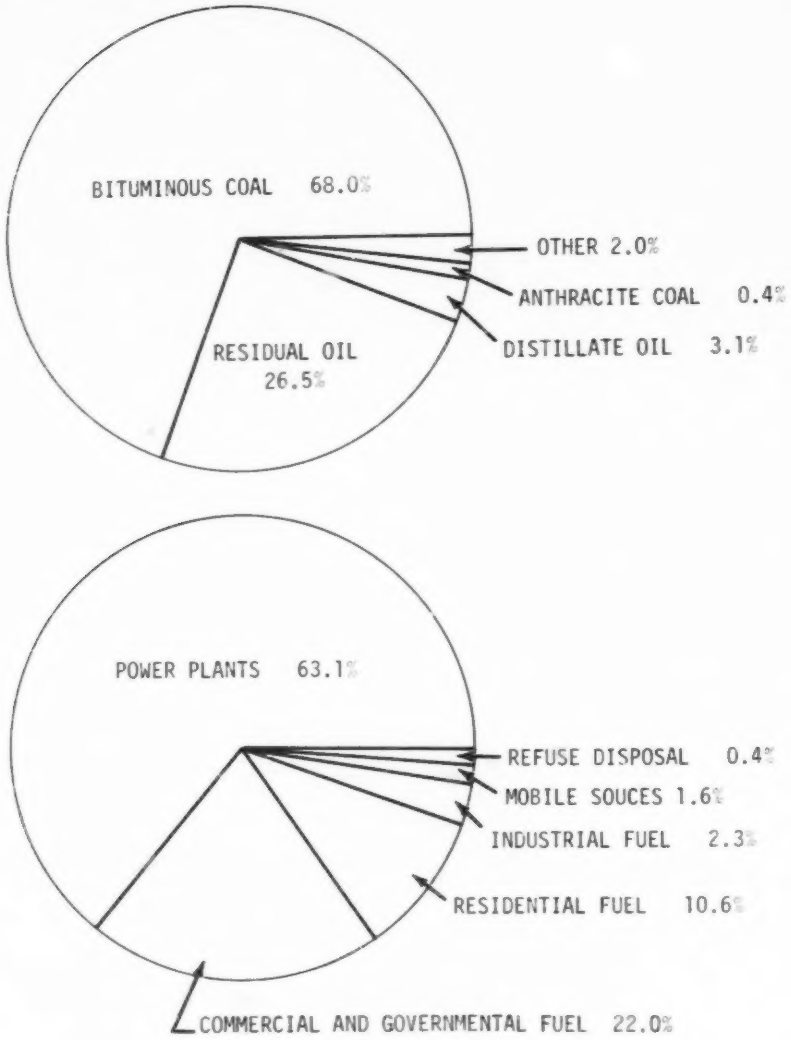


Figure 16. Sulfur oxides emitted by principal fuels (top) and by various sources (bottom)

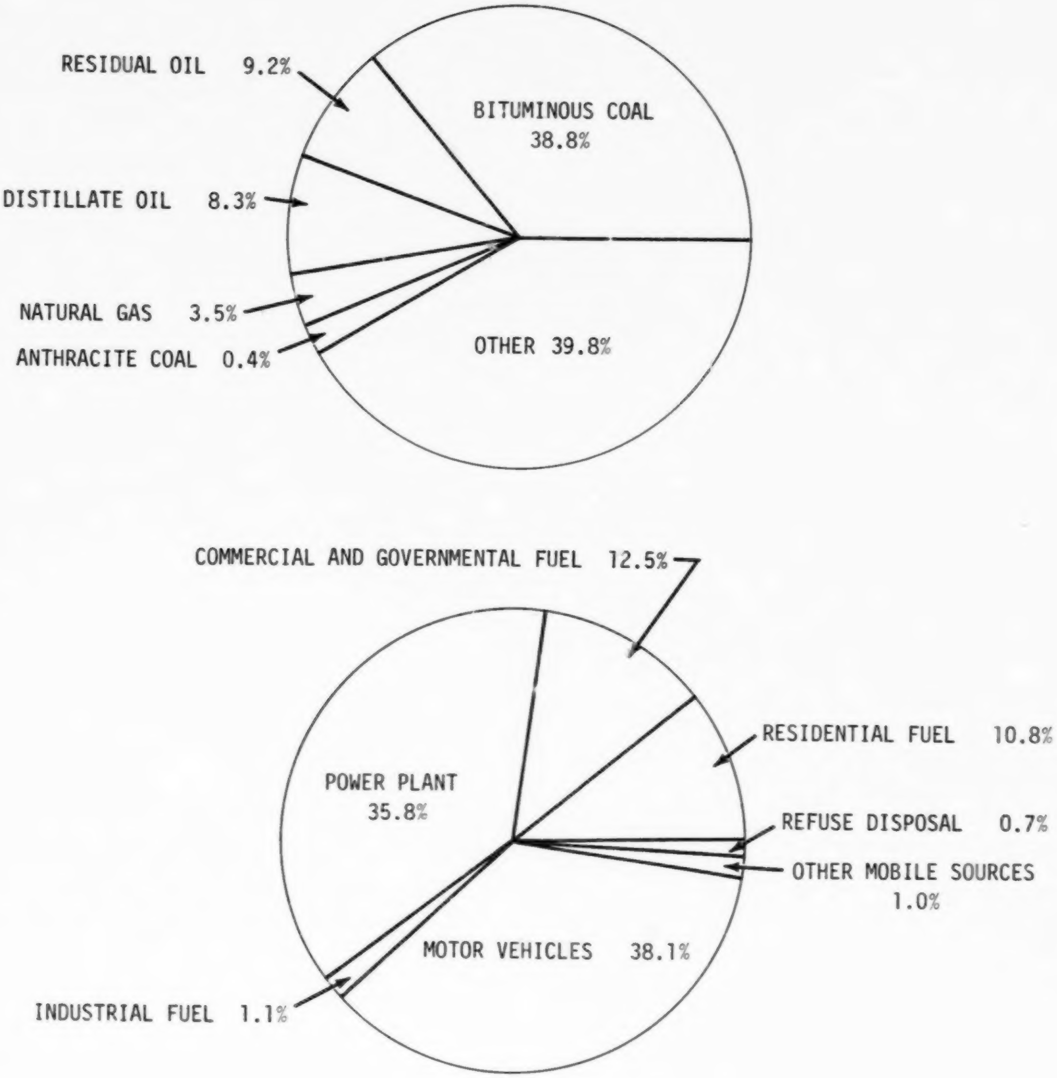


Figure 17. Nitrogen oxides emitted by principal fuels (top) and by various sources (bottom).

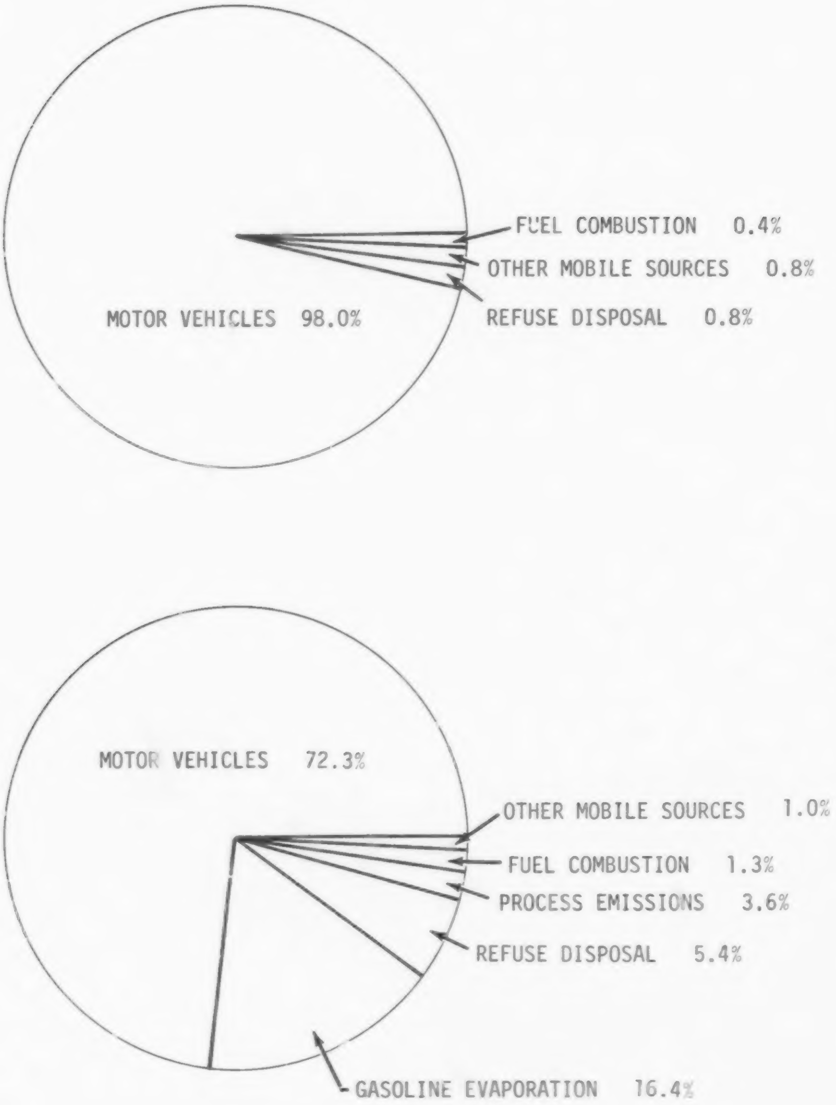
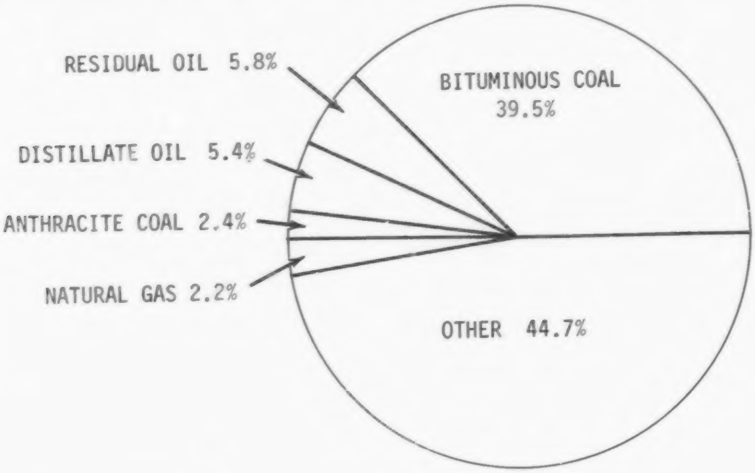


Figure 18. Carbon monoxide (top) and hydrocarbons (bottom) emitted by various sources.

motor vehicles contribute 98 percent of the annual carbon monoxide total. The other 2 percent of the carbon monoxide is emitted by fuel combustion at stationary sources, refuse burning, and aircraft operations.

The emission calculations for carbon monoxide from motor vehicles are based on amounts and types of gasoline and diesel fuel used and on the operating conditions of the vehicles.

As shown in Figure 19, particulate emissions in the metropolitan Washington, D.C., area are mainly generated by the combustion of fuel at stationary sources (56 percent of the total), refuse burning (23 percent), and mobile sources (18 percent). The other 3 percent of the particulate is emitted as process losses.



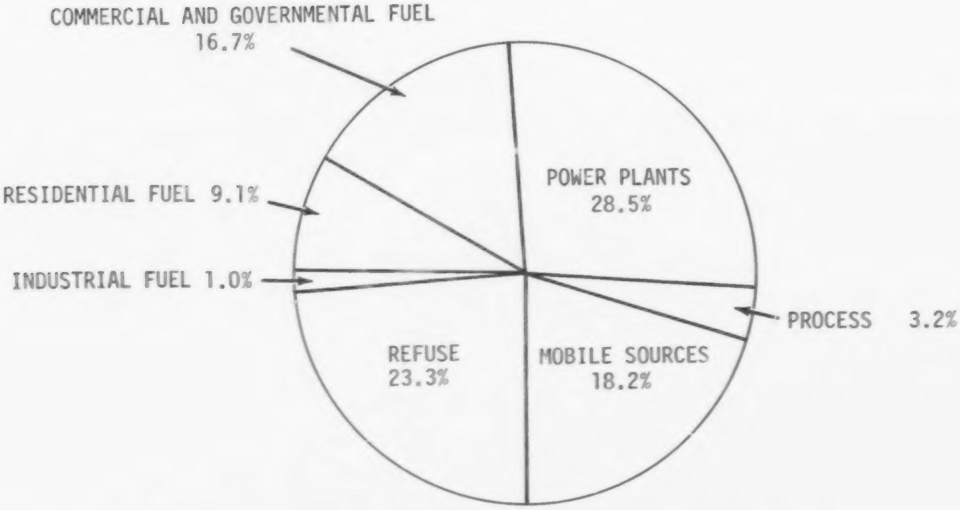


Figure 19. Particulate emitted by principal fuels (top) and by various sources (bottom).

The particulate emissions in the study area, which are primarily solid matter include both organic and inorganic material from fuel combustion, charred cellulose and ash from incineration, oxidized gasoline additives (mainly lead compounds) from motor vehicles, mineral dust from asphaltic and Portland cement batching plants, metallurgical fume, and organic and inorganic dusts from industrial processes.

The particulate inventory for combustion fuels reflects fuel quantities, ash contents, and, in some instances, control equipment. For any surveyed source, the reported fuel ash content and control equipment efficiencies or stack sampling results were used for emission calculations. Average ash contents (Appendix C) and control equipment efficiencies were used for the many small coal combustion sources distributed throughout the area. For most such area-wide sources, it was assumed that no control equipment is used on coal-fired units.

The particulate emissions from refuse burning were based on tonnage and type of material burned, method of disposal, stack sampling data, and, in some instances, control equipment efficiencies.

The greatest portion of the hydrocarbon emissions in the study area come from the blow-by and incomplete combustion of gasoline and diesel fuel by motor vehicles. Figure 18 shows that this source contributes 72 percent of the area total. The other large source of hydrocarbon emissions is gasoline evaporation (16 percent of the area total), which occurs in transferring and storing the fuel and during the normal operation of the automobile. The other 12 percent of the hydrocarbon emissions is generated by refuse disposal, solvent and process losses, fuel combustion at stationary sources, and aircraft operations.

The importance of hydrocarbon emissions is their reaction with nitrogen oxides to form photochemical smog. All hydrocarbons do not have the same reactivity in these reactions. The reactivity of hydrocarbons from automotive exhaust is usually higher than that for hydrocarbons from gasoline evaporation. Exhaust gases contain a greater quantity of olefins relative to the quantity of saturated hydrocarbons than does gasoline.

The reactivity of hydrocarbons released in process and solvent operations, such as printing and dry cleaning, can range from slightly reactive to a reactivity higher than that of automotive exhaust.

Combustion of Fuel at Stationary Sources

Coal, fuel oil, and natural gas were considered to be the only significant fuel types used in the study area for space, water, and process heating. The quantities of these fuels burned are listed by political subdivision and source type in Table 43, with emissions by fuel type listed in Table 37 through 41.

Table 43. FUEL BALANCE FOR WASHINGTON, D. C., METROPOLITAN AREA, 1965-1966

County or city	Residential fuel				
	Coal, tons		Fuel oil, 1000 gal		Natural gas, $10^6 ft^3$
	Anthracite	Bituminous	Distillate	Residual	
District of Columbia	26,700	-	56,400	43,000	15,900
Montgomery Co.	14,300	-	28,200	13,600	13,900
Prince Georges Co.	17,300	-	40,400	15,700	11,500
Maryland subtotal	31,600	-	68,600	29,300	25,400
Arlington Co.	500	1,800	12,200	16,000	4,100
Fairfax Co.	1,000	-	24,800	[illegible],000	9,400
Loudoun Co.	100	-	6,700	200	200
Prince William Co.	200	-	6,600	800	1,400
Alexandria City	4,200	700	12,500	8,100	2,500
Fairfax City	100	-	2,100	300	400
Falls Church City	100	-	2,000	100	300
Virginia subtotal	6,200	2,500	66,900	30,500	18,300
Area total	64,500	2,500	191,900	102,800	59,600

Table 43 (continued). FUEL BALANCE FOR WASHINGTON, D. C., METROPOLITAN AREA, 1965-1966

County or city	Federal Government fuel				
	Coal, tons		Fuel oil, 1000 gal.		Natural gas, $10^6 ft^3$
	Anthracite	Bituminous	Distillate	Residual	
District of Columbia	-	312,800	200	35,000	1,000
Montgomery Co.	-	-	200	18,800	100
Prince Georges Co.	-	22,400	2,400	9,600	100
Maryland subtotal	-	22,400	2,600	28,400	200
Arlington Co.	-	56,100	900	4,700	100
Fairfax Co.	-	6,500	4,300	6,600	100
Loudoun Co.	-	-	-	-	200
Prince William Co.	-	-	-	600	300
Alexandria City	-	-	-	1,300	100
Fairfax City	-	-	-	-	-
Falls Church City	-	-	-	-	-
Virginia subtotal	-	62,600	5,200	13,200	800
Area total	-	397,800	8,000	76,600	2,000

Table 43 (continued). FUEL BALANCE FOR WASHINGTON, D. C., METROPOLITAN AREA, 1965-1966

County or city	Commercial and other Governmental fuel				
	Coal, tons		Fuel oil, 1000 gal		Natural gas, $10^6 ft^3$
	Anthracite	Bituminous	Distillate	Residual	
District of Columbia	5,900	9,000	56,800	61,100	4,900
Montgomery Co.	-	7,500	10,800	9,900	1,800
Prince Georges Co.	-	30,900	10,500	16,100	2,400
Maryland subtotal	-	38,400	21,300	26,000	4,200
Arlington Co.	-	2,500	7,000	9,700	1,000
Fairfax Co.	-	24,900	7,100	13,100	1,100
Loudoun Co.	-	500	800	800	50
Prince William Co.	-	-	4,200	300	400
Alexandria City	200	3,100	4,300	6,800	800
Fairfax City	-	500	900	400	200
Falls Church City	100	500	100	400	100
Virginia subtotal	300	32,000	24,400	31,500	3,650
Area total	6,200	79,400	102,500	118,600	12,750

Table 43 (continued). FUEL BALANCE FOR WASHINGTON, D. C., METROPOLITAN AREA, 1965-1966

County or city	Industrial fuel				Steam electric power plants		
	Coal, tons	Fuel oil, 1000 gal		Natural gas, $10^6 ft^3$	Coal, tons	Fuel oil, 1000 gal	
	Bituminous	Distillate	Residual		Bituminous	Distillate	Residual
District of Columbia	2,000	600	7,900	1,500	494,300	600	700
Montgomery Co.	500	800	5,400	500	1,394,000	1,000	-
Prince Georges Co.	500	1,000	7,000	600	1,304,700	1,700	-
Maryland subtotal	1,000	1,800	12,400	1,100	2,698,700	2,700	-
Arlington Co.	500	200	600	300	-	-	-
Fairfax Co.	3,500	800	2,800	300	-	-	-
Loudoun Co.	-	50	100	-	-	-	-
Prince William Co.	-	50	200	400	824,000	-	-
Alexandria City	500	400	1,600	200	794,600	1,600	-
Fairfax City	-	-	50	50	-	-	-
Falls Church City	-	50	100	50	-	-	-
Virginia subtotal	4,500	1,550	5,450	1,300	1,618,600	1,600	-
Area total	7,500	3,950	25,750	3,900	4,811,600	4,900	700

Table 43 (continued). FUEL BALANCE FOR WASHINGTON, D. C., METROPOLITAN AREA, 1965-1966

County or city	Total fuel					Motor vehicles		Railroad diesel, 1000 gal
	Coal, tons		Fuel oil, 1000 gal		Natural gas, $10^6 ft^3$	Gasoline, 1000 gal	Diesel, 1000 gal	
	Anthracite	Bituminous	Distillate	Residual				
District of Columbia	32,600	818,100	114,600	147,700	23,300	239,800	13,200	500
Montgomery Co.	14,300	1,402,000	41,000	47,700	16,300	150,000	4,200	100
Prince Georges Co.	17,300	1,358,500	56,000	48,400	14,600	170,000	4,600	200
Maryland subtotal	31,600	2,760,500	97,000	96,100	30,900	320,000	8,800	300
Arlington Co.	500	60,900	20,300	37,000	5,500	67,800	1,900	100
Fairfax Co.	1,000	34,900	37,100	27,500	10,900	106,000	2,900	100
Loudoun Co.	100	500	7,550	1,100	450	13,400	400	50
Prince William Co.	200	824,000	10,850	1,900	2,500	30,000	800	50
Alexandria City	4,400	798,900	18,800	17,800	3,600	46,100	1,300	100
Fairfax City	100	500	3,000	750	650	17,000	500	-
Falls Church City	200	500	2,150	600	450	6,700	200	-
Virginia subtotal	6,500	1,720,200	99,650	80,650	24,050	287,000	8,000	400
Area total	70,700	5,298,800	311,250	324,450	78,250	846,800	30,000	1,200

Annual consumptions are: 70,700 tons of anthracite coal, 5.3 million tons of bituminous coal, 311 million gallons of distillate oil, 324 million gallons of residual oil, and 78 billion cubic feet of natural gas. The fraction of heat supplied by each of these fuels is shown in Figure 20.

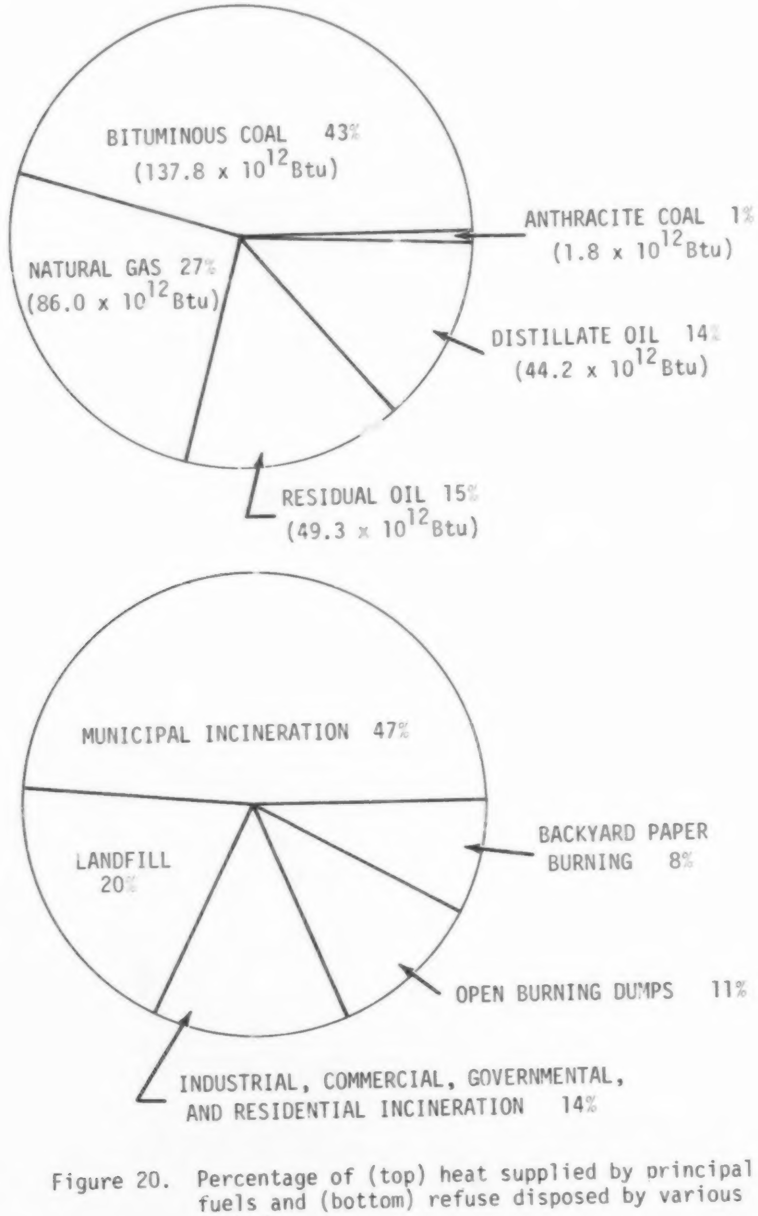


Figure 20. Percentage of (top) heat supplied by principal fuels and (bottom) refuse disposed by various methods.

Fuel oil and coal emit more pollutants to the atmosphere than does natural gas. They are significant sources of atmospheric particulates, sulfur oxides, and nitrogen oxides. The principal contaminants from the combustion of natural gas are nitrogen oxides. Table 44 is a summary of the percentages of overall emissions contributed by combustion of heating and process fuels and by type of fuel source. These data are shown in comparison to the overall emissions in Figures 37 through 40.

Table 44. CONTRIBUTIONS OF COMBUSTION FUELS AND FUEL SOURCES TO POLLUTANT EMISSIONS FOR THE METROPOLITAN WASHINGTON, D.C., STUDY AREA, 1965-1966

	Percentage of total emissions				
	SO_x	NO_x	CO	Part.	HC
Anthracite coal	0.4	0.4	0.1	2.4	0.1
Bituminous coal	68.0	38.8	0.3	39.5	0.9
Distillate oil	3.1	8.3	Neg.	5.4	0.1
Residual oil	26.5	9.2	Neg.	5.8	0.1
Natural gas	Neg.	3.5	Neg.	2.2	0.1
Residential fuel	10.6	10.8	0.1	9.1	0.3
Commercial and Governmental Fuel[a]	22.0	12.5	0.2	16.7	0.9
Industrial fuel	2.3	1.1	Neg.	1.0	Neg.
Power plants	63.1	35.8	0.1	28.5	0.1

[a] Includes Federal sources.

It is evident from the data presented that the combustion of bituminous coal contributes greatly to the pollution in the area (68 percent of the SO_x, 39 percent of the NO_x, and 39 percent of the particulate). As is shown in Table 43, commercial, governmental, and power plant sources burn 99 percent of the bituminous coal, with power plants being the main user.

Residual oil combustion is also a major source of sulfur oxides (27 percent of area total) along with bitiminous coal. This heavy oil is burned mainly by commercial and governmental sources, and high-rise apartment complexes. The burning of anthracite coal, distillate oil, and natural gas generally contributes a small percentage of the overall pollutants.

There are six power plants in the metropolitan Washington, D. C., area. Five of these plants are operated by the Potomac Electric Power Company (PEPCO) and one, by the Virginia Electric Power Company (VEPCO). Two PEPCO plants are in the District of Columbia, one in Alexandria, one in the southeastern corner of Prince Georges County, and one in the western corner of Montgomery County. The VEPCO plant is in the southeastern corner of Prince William County. All the power plants except one use pulverized-coal-firing furnaces; one older plant uses underfeed stokers. The older plant has only mechanical fly-ash collectors which operate at about-90 percent efficiency. The other plants have either a combination of mechanical and electrostatic collectors or electrostatic collectors alone. These collectors on individual coal-fired units have operating efficiencies that range from 93 to 99 percent.

As is shown in Table 44, these power plants are the largest stationary emitters of SO_x (63 percent of total), NO_x (36 percent of total), and particulate (28 percent of total). The SO_x and NO_x emissions result from the large quantities of bituminous coal used; the sulfur content of the coal accounts for the SO_x emissions. No on-site control is used for the SO_x and NO_x emissions. The particulate emissions are great, 9,900 tons/year, but would be much greater, 312,600 tons/year, if no control were exercised.

Commercial and all governmental fuel-burning sources also contribute greatly to the SO_x, NO_x and particulate emissions problem. Table 44 and Figures 16 through 19 show the contributions of each category of source. Much of these emissions are from the combustion of bituminous coal and residual oil at Federal government facilities. These Federal sources burn 398,000 tons of bituminous coal and 76.6 million gallons of residual oil annually. The emissions from the Federal sources are tabulated in Tables 37 through 41.

Ten Federal locations burn bituminous coal. These include small operations at military bases, a hospital, and the large heating plants in the District and Arlington County. These plants are mainly fired with underfeed stokers, although a small amount of the coal is fired with spreader stokers. The control equipment for these plants ranges from no control on the small units to 95 percent efficient electrostatic precipitators on some of the units in the large heating plants.

Commercial and non-Federal governmental fuel-burning sources also emit quite a large portion of the pollutants because of the quantity of distillate oil, residual oil and bituminous coal burned. These sources contribute 12 percent of the area SO_x, 6 percent of the NO_x total and 1 percent of the area particulate.

Residential fuel burning sources contribute almost 10 percent of the SO_x, NO_x and particulate totals for the study area. These emissions reflect the large usage of distillate and residual oil and the inefficient burning of hand-fired and underfeed stokers that use anthracite coal. The only large residential usage of residual oil is in large apartment complexes.

Due to the absence of any large concentration of industry, industrial fuel burning accounts for a small portion of the emission totals, 2 percent or less for all pollutants.

Process and Solvent Losses

In general, the Washington, D. C., area is free of any large industrial process emissions. The emissions from this source category are mainly particulates and hydrocarbons. No significant process sources of sulfur oxides, nitrogen oxides, or carbon monoxide were located in the survey.

The main sources of particulate process emissions are asphalt and concrete batch operations, small gray-iron foundries, coffee roasting, and some small miscellaneous chemical operations. There are no large single sources of these particulate emissions, but as a group they contributed 3 percent of the area particulate.

Hydrocarbon losses from the use of solvents in dry cleaning operations; Federal, commercial, and industrial printing and engraving; and industrial painting account for 4 percent of the area hydrocarbon total. Stoddard solvents are used in printing and engraving operations, and perchloroethylene- and petroleum-base solvents are used in the dry cleaning and industrial paint industry, respectively.

Refuse Disposal

The amounts of refuse disposed of in the area by the various techniques are listed in Table 45. Disposal of refuse by burning accounts for 23 percent of the particulate emissions; 5 percent of the hydrocarbons; and less than 1 percent of the SO_x, NO_x, and carbon monoxide emissions.

The burning of refuse contributes to the particulate problem; the main area of concern is open-burning dumps. There is one such dump in the District of Columbia, one in the city of Alexandria, one in Prince William County, and three in Prince Georges County. These dumps account for only 11 percent (Figure 20 - page 86) of the total refuse disposed but contribute 47 percent of the particulate emissions from refuse disposal.

The other problem of concern is that 47 percent of the refuse is municipally incinerated within the areas of greatest population density. There are seven municipal incinerators in the study area, four in the District of Columbia, and one each in the city of Alexandria, Arlington County and Montgomery County. This municipal incineration accounts for 23 percent of the particulate emissions from refuse disposal.

Table 45. REFUSE DISPOSAL IN WASHINGTON, D.C., METROPOLITAN AREA, 1965-1966
(tons/year)

City or county	Landfill	Open-burning[a] dump	Municipal incineration	On-site[a] incineration	Backyard paper burning	Total[a]	Federal incineration	Federal open burning	Total Federal
District of Columbia	-	114,300	345,300	32,000	-	491,600	11,750[b]	114,300	126,050
Montgomery Co.	-	-	193,000	42,100	7,700	242,800	13,000	-	13,000
Prince Georges Co.	162,400	21,900	-	24,200	36,000	244,500	b	-	-
Maryland subtotal	162,400	21,900	193,000	66,300	43,700	487,300	13,000	-	13,000
Arlington Co.	-	-	80,800	24,200	-	105,000	5,300	-	5,300
Fairfax Co.	122,200	-	-	52,500	38,300	213,000	b	-	-
Loudoun Co.	-	-	-	6,600	12,900	19,500	-	-	-
Prince William Co.	-	15,000	-	8,000	10,700	33,700	b	-	-
Alexandria City	-	10,000	60,500	10,700	-	81,200	3,000	-	3,000
Fairfax City	-	-	-	3,400	1,600	5,000	-	-	-
Falls Church City	-	-	-	2,300	1,100	3,400	-	-	-
Virginia subtotal	122,200	25,000	141,300	107,700	64,600	460,800	8,300	-	8,300
Area total	284,600	161,200	679,600	206,000	108,300	1,439,700	33,050	114,300	147,350

[a] Includes Federal sources.

Refuse is also burned in on-site, flue-fed, single- and multiple-chamber incinerators. This is done mainly in the urban areas and consists of residential, commercial, governmental, and industrial burning. Backyard open-burning of paper and leaves is done mainly in the suburban areas. This on-site incineration and backyard open-burning account for the other 30 percent of the particulate from refuse disposal.

There are four landfill operations in Prince Georges County and one in Fairfax County. These landfills account for disposal of 20 percent of the refuse generated in the study area.

Included in the refuse disposal category are the emissions from automobile burning. The main pollutant of concern from this burning is particulate, although there are emissions of carbon monoxide and hydrocarbons. The particulate emissions from automobile burning in the Washington, D. C., area account for less than 1 percent of the overall particulate total. Even though this source on an area-wide basis is negligible compared to coal-combustion, and refuse burning, it does present a local nuisance.

Fuel Combustion by Mobile Sources

Sources included in this category are motor vehicles (gasoline and diesel powered), railroads, and aircraft. The total fuel usage by motor vehicles and railroads is shown in Table 43. The emission calculations for these two sources were based on these totals. Aircraft emissions calculations for the three major airfields in the area (Washington National Airport, Dulles International Airport, and Andrews Air Force Base) were based on take-off, landing, and taxi operations.

The amounts and percentages of each pollutant emitted by mobile sources are shown in Tables 37 through 41 and Figures 16 through 19. It is quite evident that motor vehicles are by far the greatest source of carbon monoxide (98 percent of the total) in the area. Almost 100 percent of the carbon monoxide emitted by motor vehicles emanates from the automobile. The burning of fuel by motor vehicles is also the largest single source of hydrocarbons (72 percent of the total) and nitrogen oxides (38 percent of the total).

The particulate emissions from mobile sources account for 18 percent of the area-wide total emissions. Aircraft and railroad operations contribute 2 percent, and motor vehicles produce 16 percent. Mobile sources produce only 2 percent of the sulfur oxides emitted in the area.

It is evident from the data presented that mobile sources in the Washington, D. C., area contribute largely to the overall pollution problem; the main mobile source category is automobiles. It should be noted that aircraft operations contribute a small portion of the particulate, hydrocarbon, and oxides of nitrogen emissions.

Gasoline Evaporation

The pollutant of concern in gasoline evaporative losses is hydrocarbons. From Figure 18 it can be seen that 16 percent of the area-wide hydrocarbon emissions come from this source. Seventy-seven percent (38,900 tons) of these evaporative hydrocarbons are emitted from the fuel tanks and carburetors of automobiles. The other 23 percent of these hydrocarbon losses are from the loading of tank vehicles and the filling of service station storage tanks and automobile fuel tanks.

Summary of Emissions from Federal Sources

A large number of Federal facilities are located in the metropolitan Washington, D. C., area. The air pollutant emissions from Federal sources by political subdivision are listed in Tables 37 through 41. The tabulated emissions from Federal sources include those from fuel combustion, refuse burning, aircraft operations, and solvent usage. No separate estimation was made concerning emissions from Federally owned motor vehicles.

The main concentration of Federal sources is in the District of Columbia. As shown in Table 46, these sources contribute 27 percent of the SO_x, 13 percent of the NO_x, 2 percent of the carbon monoxide, 35 percent of particulate, and 6 percent of the hydrocarbons emitted in the District. Federal sources account for substantially lower percentages of the total emissions for the entire study area.

Fuel combustion at Federal facilities contributes to the emissions of SO_x, NO_x, and particulate in the area. The estimated Federal fuel usage is listed in Table 43. The emissions are mainly from the bituminous coal used at the large heating plants and from the millions of gallons of residual oil used at the various military installations and other Federal facilities in the area.

The burning of refuse at Federal facilities accounts for 8 percent of the particulate emitted in the study area. This arises from on-site incineration at the various facilities and the large open-burning dump in the District of Columbia. This dump, which is one of the main sources of particulate from Federal sources, accounts for 24 percent of the particulate pollution emitted in the District.

The three major airfields in the study area are Federally operated. They generate a small portion of the total pollutant emissions. As can be seen from Table 46, they contribute 1 percent of the NO_x, carbon monoxide, and particulate and 2 percent of the area's hydrocarbons.

The hydrocarbon emissions from Federal usage of solvents in their printing and engraving operations in the District of Columbia account for less than 1 percent of the District's hydrocarbon emissions. This solvent evaporation accounts for even less of the area-wide hydrocarbon total.

Table 46. CONTRIBUTION OF FEDERAL SOURCES TO POLLUTANT EMISSIONS IN WASHINGTON, D.C.- METROPOLITAN AREA, 1965-1966

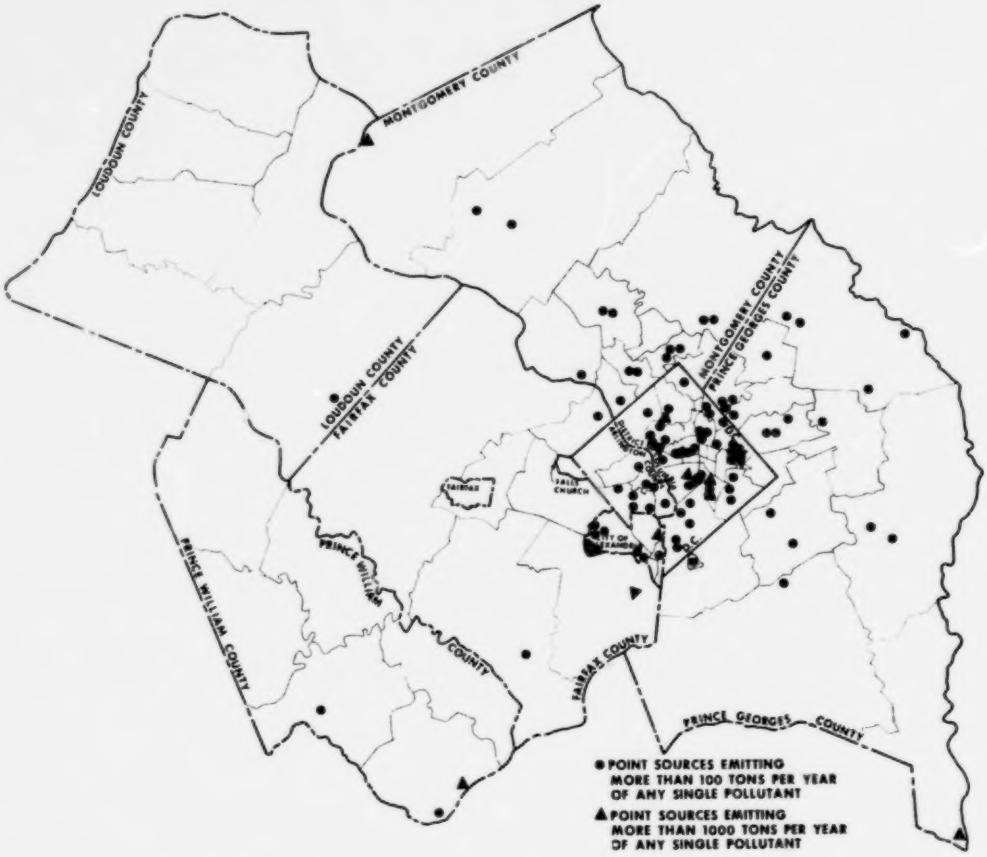
	Percent of emissions				
	SO_x	NO_x	CO	Particulate	HC
District of Columbia	26.7	13.2	1.6	34.7	6.0
Fuel	62.7	13.2	0.2	10.3	0.1
Refuse	Neg.	Neg.	1.4	24.4	5.3
Aircraft operations	-	-	-	-	-
Solvent usage	-	-	-	-	0.6
Total emissions in District of Columbia tons/year	16,110	4,560	5,600	3,890	5,335
Total study area	10.0	6.6	1.3	15.8	2.8
Fuel	10.0	5.7	Neg.	6.1	Neg.
Refuse	Neg.	Neg.	0.5	8.3	1.7
Aircraft operations	Neg.	0.9	0.8	1.4	0.9
Solvent usage	-	-	-	-	0.2
Total emissions from Federal sources in total study area, tons/year	24,775	8,830	15,745	5,460	8,675

Point Sources

Any individual site in the survey area that emitted 100 tons or more per year of any single pollutant was considered to be a point source. There were 99 such sources. These sources include 6 steam-electric power plants, 7 municipal incinerators, 5 open-burning dumps, 3 airfields (includes fuel combustion and aircraft operations), 2 industrial process operations, 32 Federal fuel combustion facilities, and 44 other governmental, commercial, residential and industrial fuel combustion operations.

On a yearly basis these 99 point sources contribute 191,000 tons of SO_x (77 percent of total), 60,000 tons of NO_x (44 percent of total), and 21,000 tons of particulate (60 percent of total). They emit a small percentage of the carbon monoxide and hydrocarbon emissions. The stationary fuel combustion point sources account for 99 percent of the bituminous coal burned, 37 percent of the residual oil burned, and

4 percent of the distillate oil burned. Overall, these combustion sources account for 49 percent of the total fuel burned in the study area. Point sources are located on the map of Figure 21.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FALLS CHURCH
CITY OF ALEXANDRIA
PRINCE WILLIAM
COUNTY
PRINCE WILLIAM COUNTY
FAIRFAX COUNTY
PRINCE GEORGES COUNTY
● POINT SOURCES EMITTING MORE THAN 100 TONS PER YEAR OF ANY SINGLE POLLUTANT
▲ POINT SOURCES EMITTING MORE THAN 1000 TONS PER YEAR OF ANY SINGLE POLLUTANT

Figure 21. Point sources that emit 100 tons or more per year of a single pollutant.

Variation in Pollutants Due to Space Heating

Increased fuel burning during space-heating days results in greater pollutant emissions than occur on days when space heating is not required. This is illustrated in Tables 47 and 48. The variation in emission values between a minimum and maximum space-heating day is greater for SO_x than for any of the other four pollutants because 95 percent of the SO_x emissions are from the combustion of bitiminous coal and residual oil. The use of these two fuels by residential, commercial and governmental sources is mainly for space-heating purposes.

Table 48. SOURCES OF EMISSIONS FOR MINIMUM, AVERAGE, AND MAXIMUM SPACE HEATING DAYS IN WASHINGTON, D.C., METROPOLITAN AREA, 1965-1966
(tons/day)

Source type	SO_x			NO_x			CO			Particulates			HC		
	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max
Residential fuel	17	103	227	10	58	124	Neg	6	18	1	12	26	Neg	3	4
Commercial and Governmental fuel	-	231	556	-	72	177	-	11	26	-	26	61	-	4	11
Industrial fuel	18	23	30	5	5	9	Neg	Neg	Neg	1	2	2	Neg	Neg	Neg
Power plants	537	426	396	166	133	125	4	4	4	32	27	26	1	Neg	Neg
Process emissions	-	-	-	-	-	-	-	-	-	5	5	5	38	38	38
Motor vehicles	10	10	10	142	142	142	3518	3518	3518	16	16	16	615	615	615
Gasoline evaporation	-	-		-	-	-	-	-	-	-	-	-	139	139	139
Railroads	Neg	Neg		Neg	Neg	Neg	Neg	Neg	Neg	Neg	Neg	Neg	Neg	Neg	Neg
Airplanes	-	-		3	3	3	27	27	27	2	2	2	8	8	8
Refuse burning	3	3		2	2	2	32	32	32	28	28	28	71	71	71
Total	585	796	1222	328	415	582	3581	3598	3625	85	118	166	872	878	886

Table 47. EMISSIONS FOR MINIMUM, AVERAGE, AND MAXIMUM SPACE HEATING DAYS IN WASHINGTON, D.C., METROPOLITAN AREA, 1965-1966
(tons/day)

County or city	SO_x			NO_x			CO			Particulates			HC		
	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max
District of Columbia	91	230	467	71	114	191	975	983	995	27	39	57	245	248	252
Montgomery Co.	169	204	253	66	83	106	602	604	608	16	20	25	145	146	147
Prince Georges Co.	214	191	227	86	87	107	697	700	704	19	27	40	180	181	183
Maryland subtotal	383	395	480	152	170	213	1299	1304	1312	35	47	65	325	327	330
Arlington Co.	5	33	73	13	24	38	420	421	422	4	7	11	67	67	67
Fairfax Co.	4	28	61	20	31	48	425	428	433	5	9	15	113	114	115
Loudoun Co.	Neg.	2	4	3	4	6	56	56	56	Neg.	Neg.	Neg.	18	18	18
Prince William Co.	41	44	49	28	30	34	123	123	123	8	8	10	34	34	34
Alexandria City	61	63	84	37	37	45	188	188	189	6	8	8	47	47	47
Fairfax City	Neg.	1	2	3	4	5	68	68	68	Neg.	Neg.	Neg.	16	16	16
Falls Church City	Neg.	Neg.	2	1	1	2	27	27	27	Neg.	Neg.	Neg.	7	7	7
Virginia subtotal	111	171	275	105	131	178	1307	1312	1318	23	32	44	302	303	304
Area total	585	796	1222	328	415	582	3581	3598	3625	85	118	166	872	878	886

As is seen in Table 48, steam-electric power plant emissions are greatest on a minimum space-heating day. This is due to the use of two of the plants as peak operating stations, and to the fact that the greatest electrical load in most of the areas is in the summer when there is a large demand for air conditioning.

Variations in the NO_x and particulate emissions also reflect the space-heating use of fuel, but not so markedly as do the SO_x variations. This is consistent with the fact that a large portion of the NO_x (40 percent) and particulate (44 percent) emissions are generated by sources that operate at approximately the same rate throughout the year, i.e., industrial processes, refuse burning, motor vehicles, and aircraft.

The carbon monoxide and hydrocarbon variations due to space-heating are small because nearly all of these emissions emanate from motor vehicle engines and evaporative losses, sources which are relatively constant throughout the year.

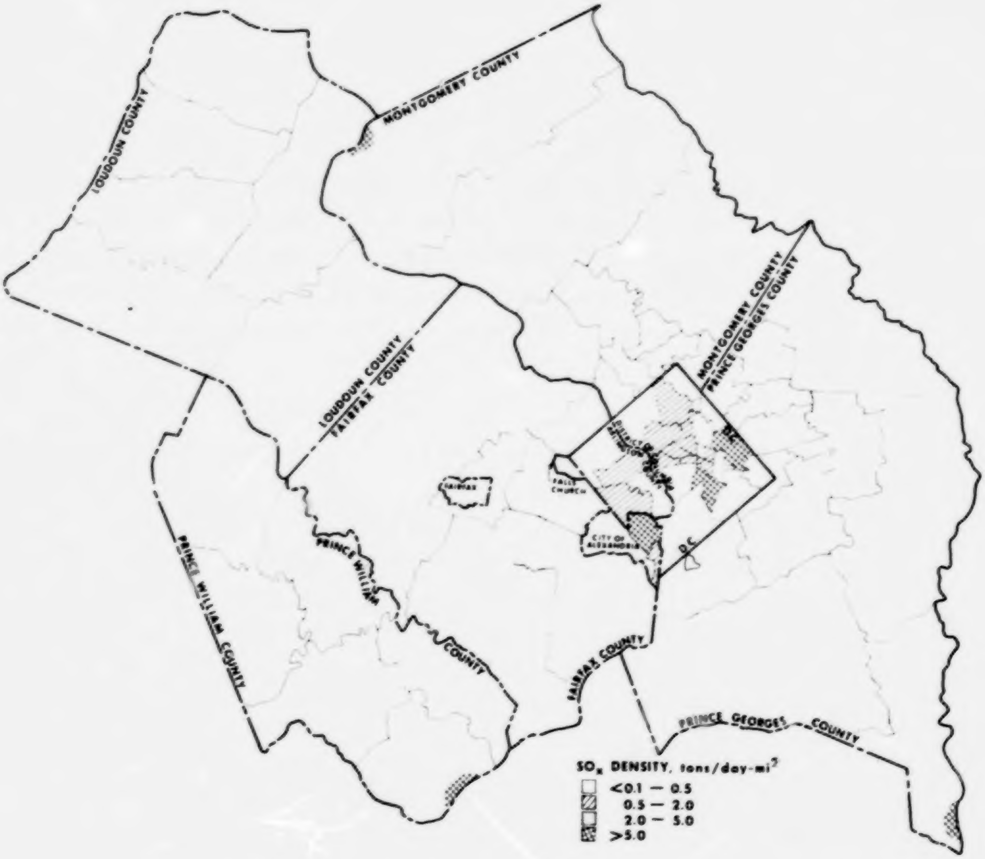
The pollutant emission densities for the various political subdivisions, as shown in Table 47, reflect the concentration of residential, commercial and governmental sources in the District of Columbia, Arlington County, and Fairfax County. The lack of a large variation in emissions during different space-heating periods for the populated areas of Montgomery and Prince Georges Counties and the City of Alexandria is due to the large power plant emissions.

In Appendix D, emission densities in tons per day per square mile are listed for SO_x, NO_x, and particulates on minimum, average and maximum space-heating days for each of the emission zones in the study area. The listings for carbon monoxide and hydrocarbons are presented only for an average space-heating day because their emissions are almost constant for the three types of days. These emission densities are plotted for areas of equal concentration in Figures 22 through 32. Since zones are considerably smaller than counties, these values in some instances show sharp differences in emission levels where major point sources are concerned.

METEOROLOGICAL REPRESENTATIVENESS

It was necessary to determine whether the atmospheric conditions during the sampling period were representative of those normally experienced in the Washington, D. C., area during the first 7 months of the year. Having made this determination, it was then possible to form judgments as to the representativeness of the air quality data.

General climatological data and current meteorological observations are available at the U.S. Weather Bureau Office at National Airport. Thus, to determine representativeness, observations made at the airport, during the sampling period, January through July 1967, were analyzed and compared with climatological data from the same site for the period January through July for the 10 years 1951 through 1960.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CITY OF ALEXANDRIA
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PRINCE WILLIAM
COUNTY
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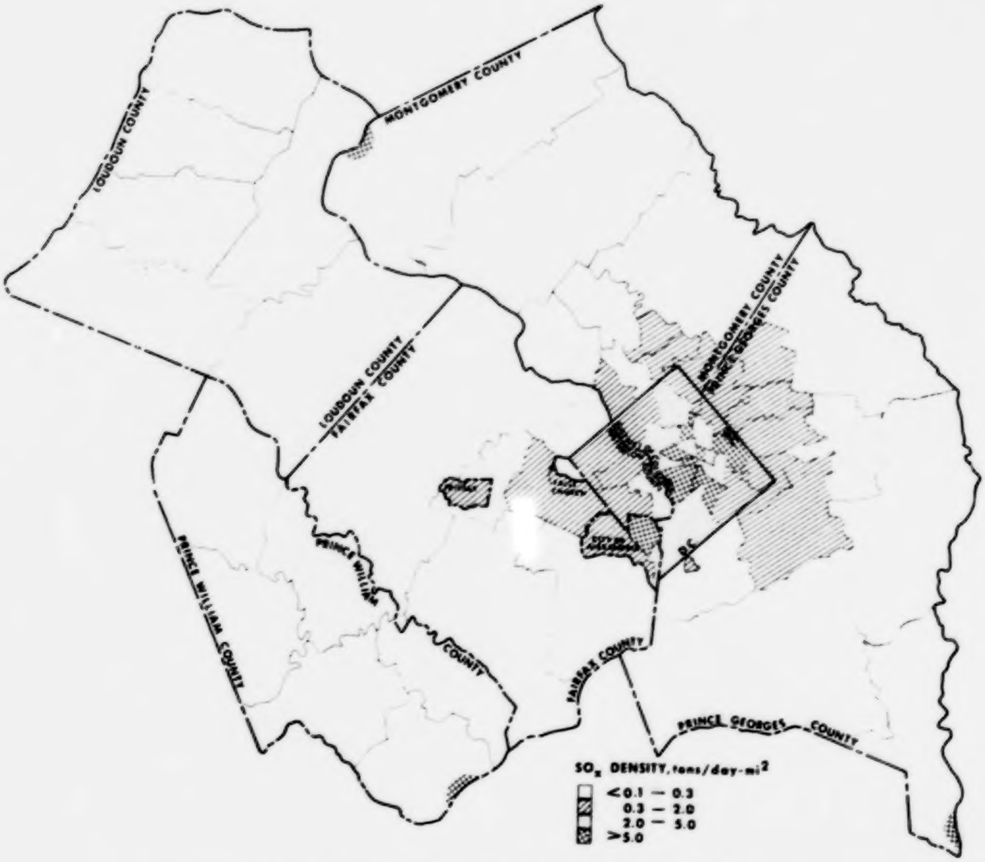
PRINCE GEORGES COUNTY
SO$_x$ DENSITY, tons/day-mi^2
☐ <0.1 — 0.5
▨ 0.5 — 2.0
☐ 2.0 — 5.0
▩ >5.0

Figure 22. Sulfur oxides emission densities for a minimum space-heating day.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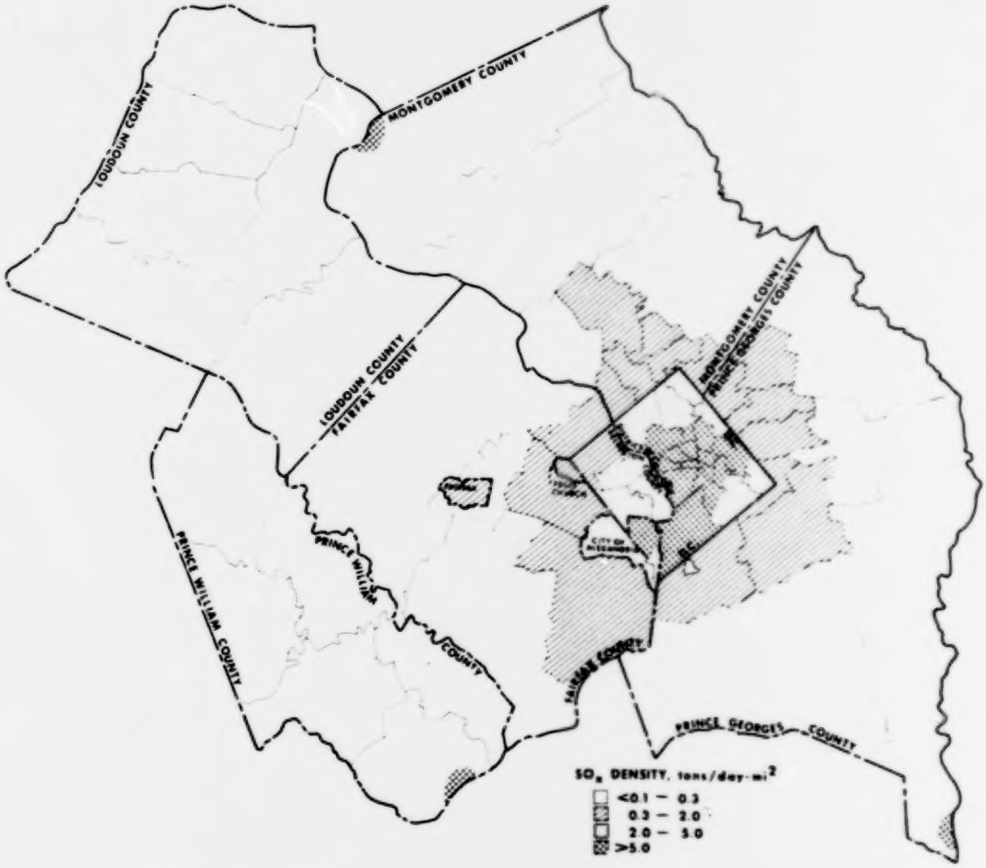
SO_x DENSITY, tons/day-mi^2
<0.1 — 0.3
0.3 — 2.0
2.0 — 5.0
>5.0

Figure 23. Sulfur oxides emission densities for an average space-heating day.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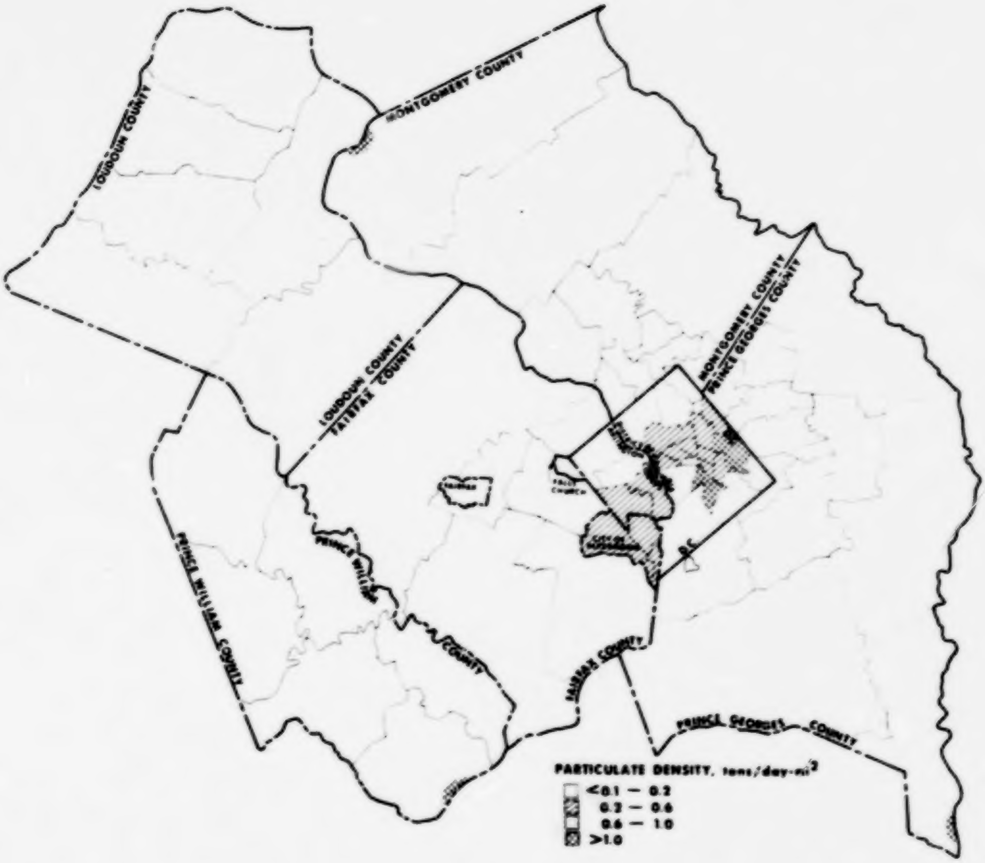
D.C.
SO_x DENSITY, tons/day-mi^2
☐ <0.1 — 0.3
▨ 0.3 — 2.0
☐ 2.0 — 5.0
▩ >5.0

Figure 24. Sulfur oxides emission densities for a maximum space-heating day.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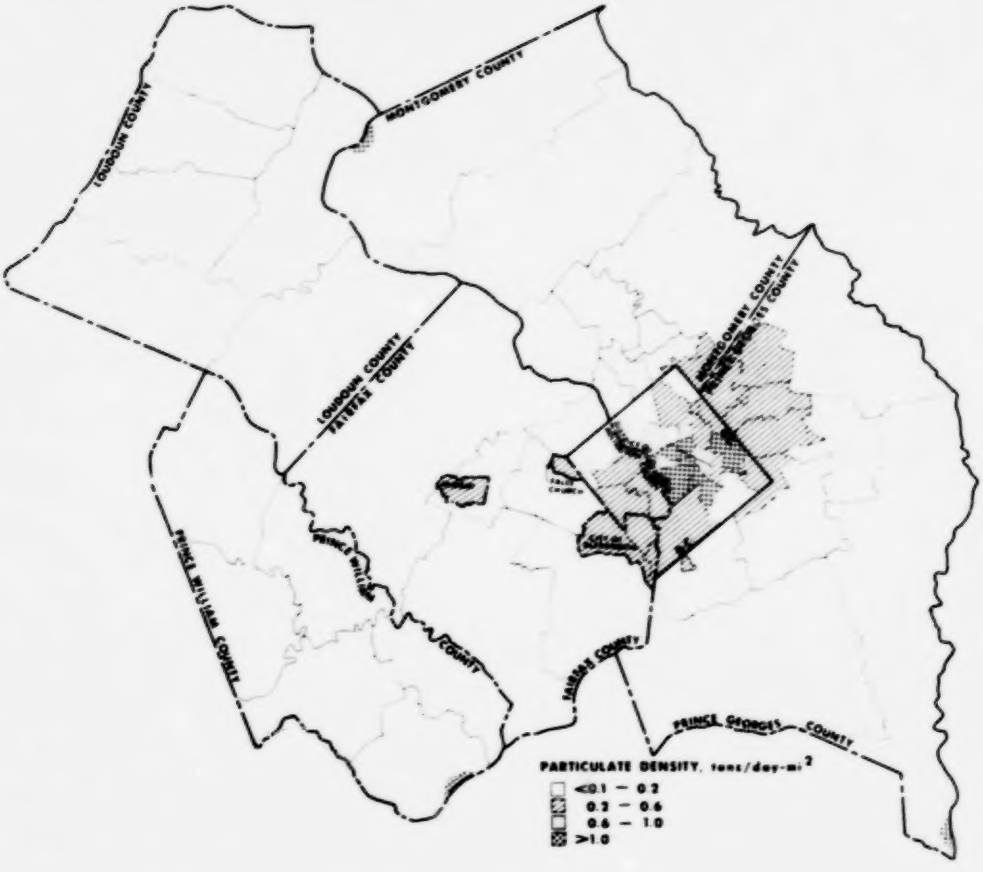
CITY OF ALEXANDRIA
D.C.
PRINCE WILLIAM COUNTY
PRINCE WILLIAM COUNTY
FAIRFAX COUNTY
PRINCE GEORGES COUNTY
PARTICULATE DENSITY, tons/day-mi²
<0.1 — 0.2
0.2 — 0.6
0.6 — 1.0
>1.0

Figure 25. Particulate emission densities for a minimum space-heating day.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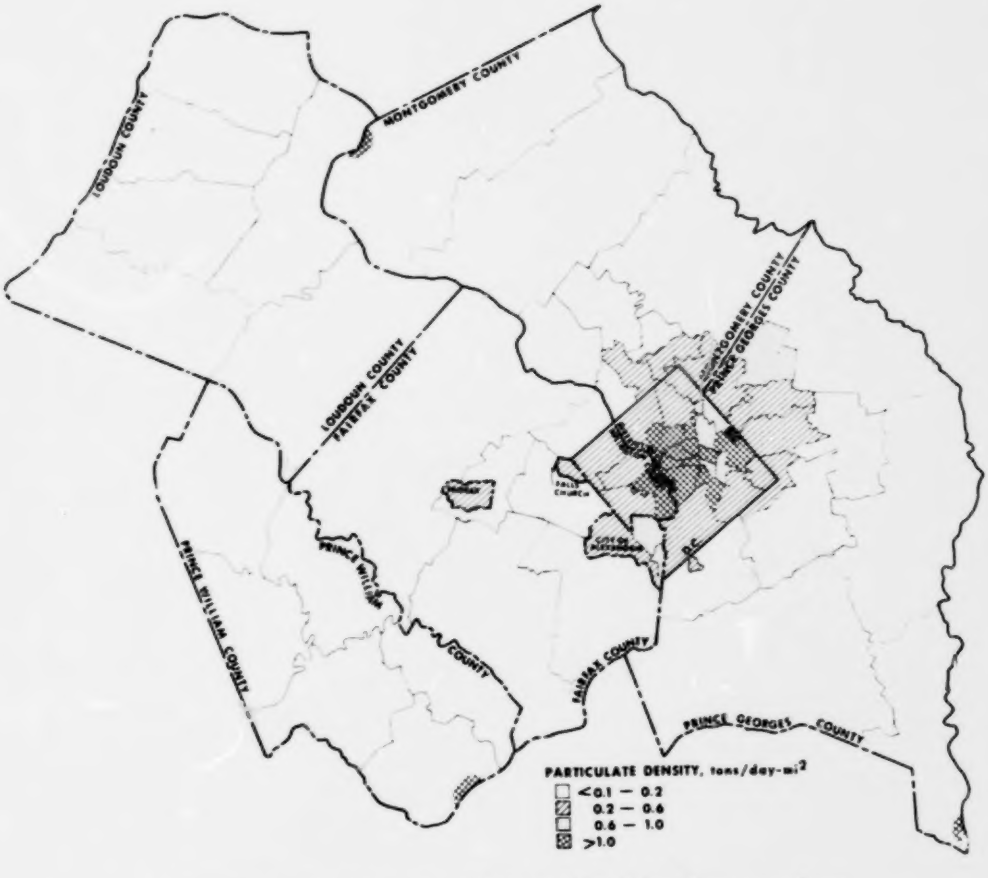
FAIRFAX COUNTY
PRINCE GEORGES COUNTY
PARTICULATE DENSITY, tons/day-mi²
☐ <0.1 — 0.2
▨ 0.2 — 0.6
☐ 0.6 — 1.0
▩ >1.0

Figure 26. Particulate emission densities for an average space-heating day.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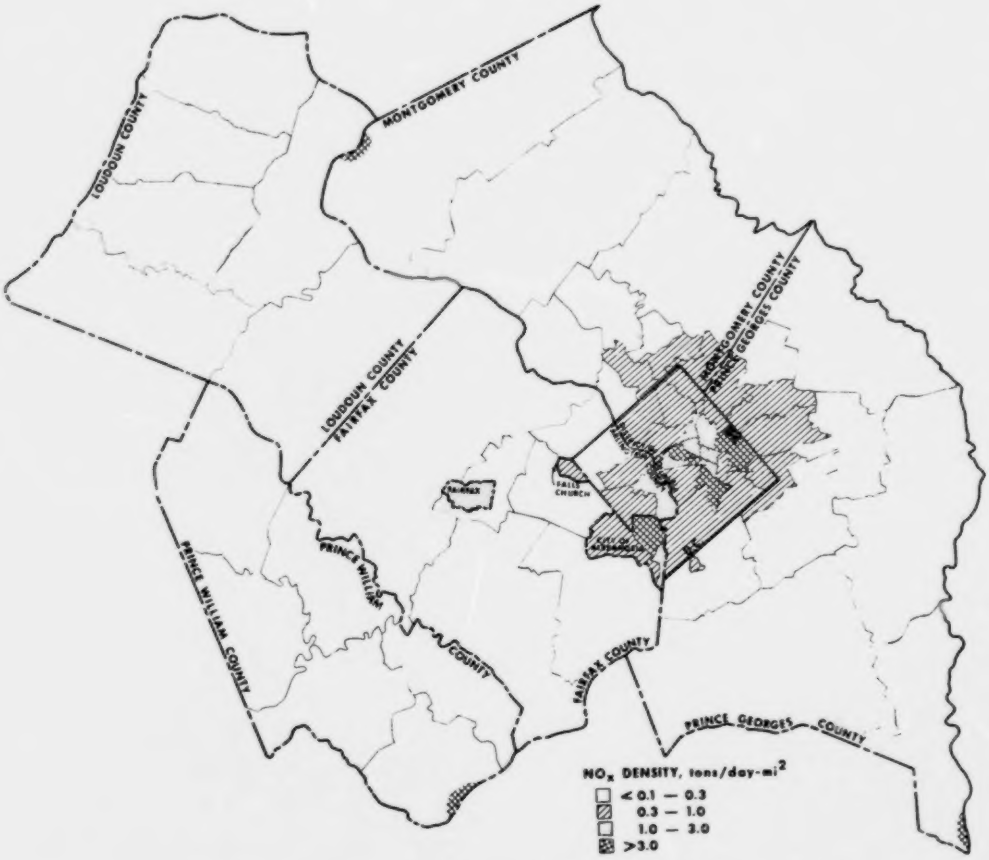
FAIRFAX COUNTY
PRINCE GEORGES COUNTY
PARTICULATE DENSITY, tons/day-mi²
☐ <0.1 — 0.2
▨ 0.2 — 0.6
☐ 0.6 — 1.0
▩ >1.0

Figure 27. Particulate emission densities for a maximum space-heating day.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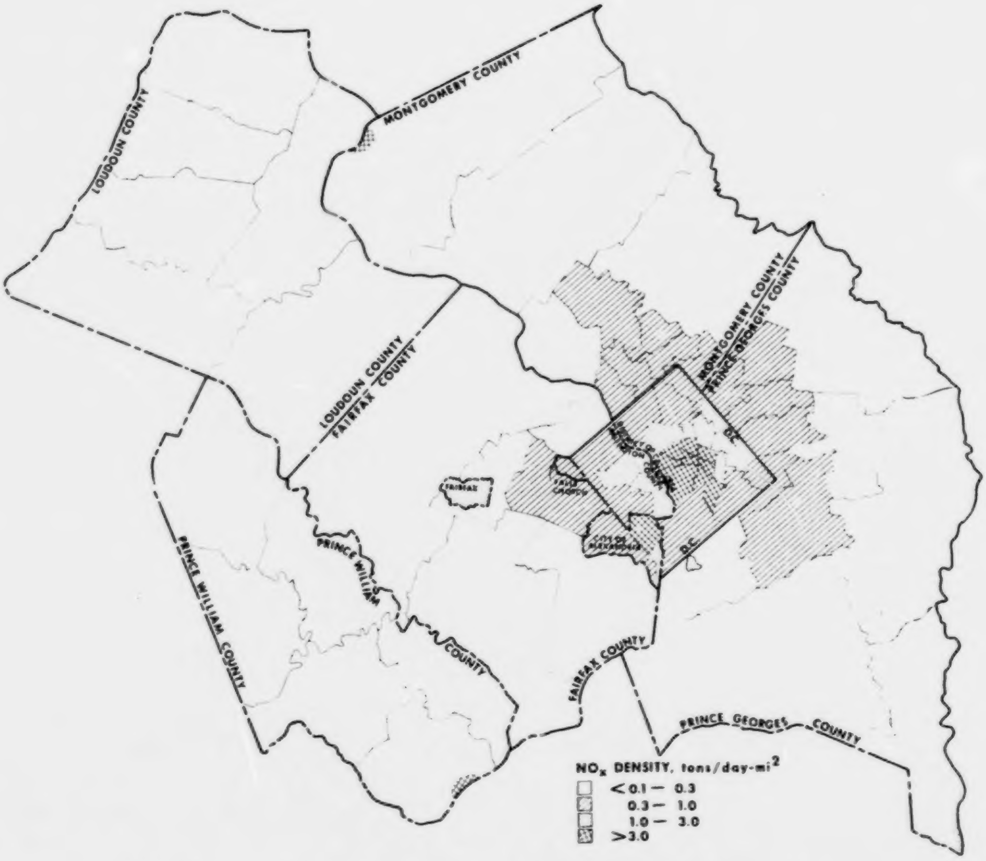
PRINCE WILLIAM COUNTY
FAIRFAX COUNTY
PRINCE GEORGES COUNTY
NO$_x$ DENSITY, tons/day-mi^2
☐ < 0.1 — 0.3
▨ 0.3 — 1.0
☐ 1.0 — 3.0
▩ >3.0

Figure 28. Nitrogen oxides emission densities for a minimum space-heating day.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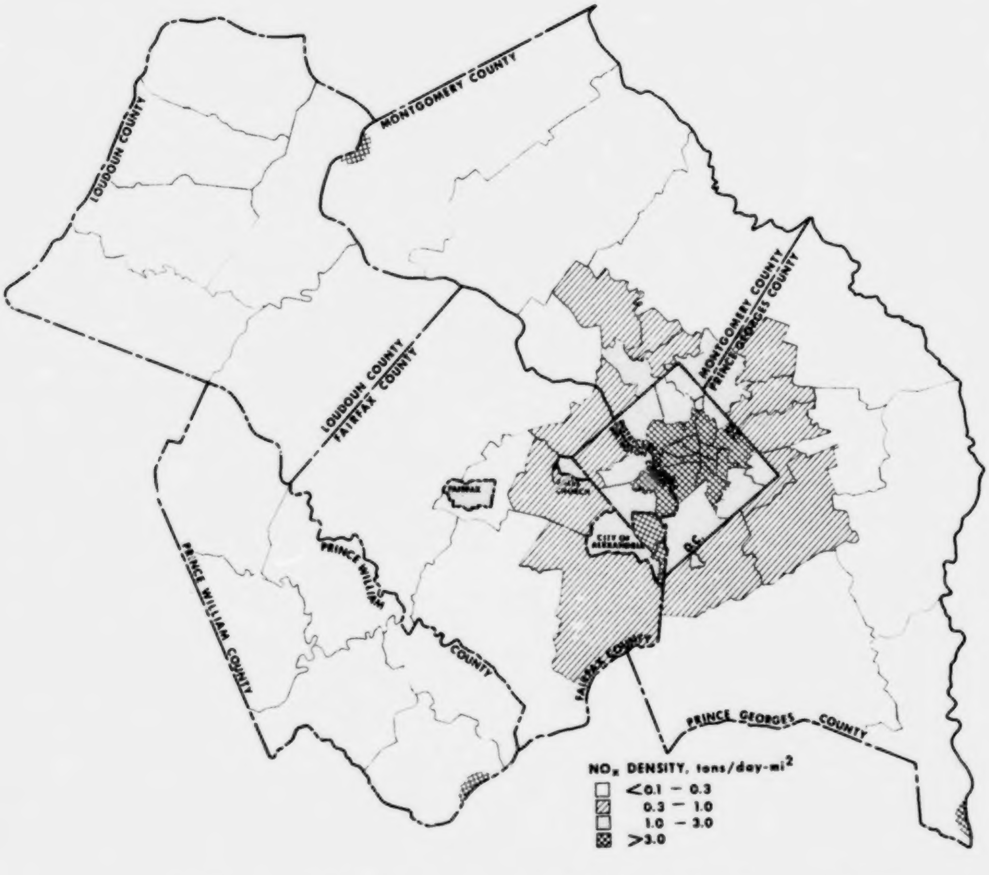
CITY OF ALEXANDRIA
D.C.
PRINCE WILLIAM COUNTY
PRINCE WILLIAM COUNTY
FAIRFAX COUNTY
PRINCE GEORGES COUNTY
NO_x DENSITY, tons/day-mi^2
☐ <0.1 — 0.3
▨ 0.3 — 1.0
☐ 1.0 — 3.0
▩ >3.0

Figure 29. Nitrogen oxides emission densities for an average space-heating day.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PRINCE WILLIAM COUNTY
PRINCE WILLIAM
COUNTY
FAIRFAX COUNTY
PRINCE GEORGES COUNTY
NO$_x$ DENSITY, tons/day-mi^2
☐ <0.1 – 0.3
▨ 0.3 – 1.0
☐ 1.0 – 3.0
▩ >3.0

Figure 30. Nitrogen oxides emission densities for a maximum space-heating day.

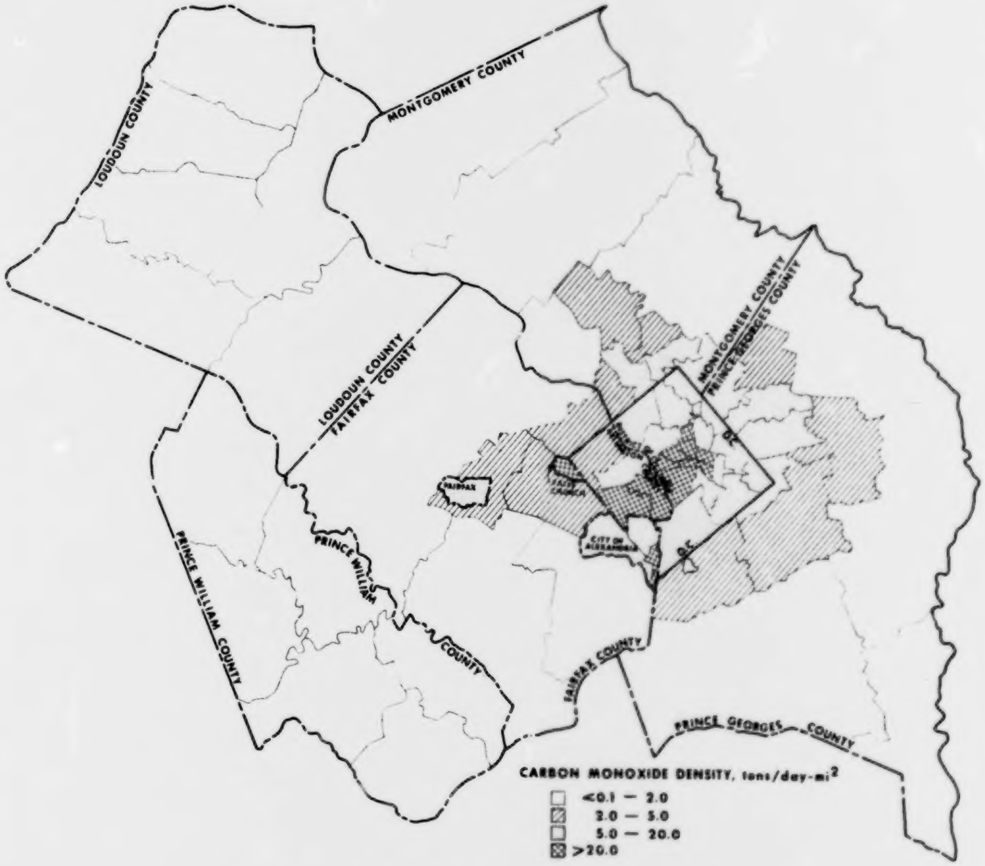
LOUDOUN COUNTY
MONTGOMERY COUNTY
LOUDOUN COUNTY
FAIRFAX COUNTY
MONTGOMERY COUNTY
PRINCE GEORGES COUNTY
FAIRFAX
FALLS CHURCH
CITY OF ALEXANDRIA
D.C.
D.C.
PRINCE WILLIAM COUNTY
PRINCE WILLIAM
COUNTY
FAIRFAX COUNTY
PRINCE GEORGES COUNTY
CARBON MONOXIDE DENSITY, tons/day-mi^2
☐ <0.1 — 2.0
▨ 2.0 — 5.0
☐ 5.0 — 20.0
☒ >20.0

Figure 31. Carbon monoxide emission densities for an average space-heating day.

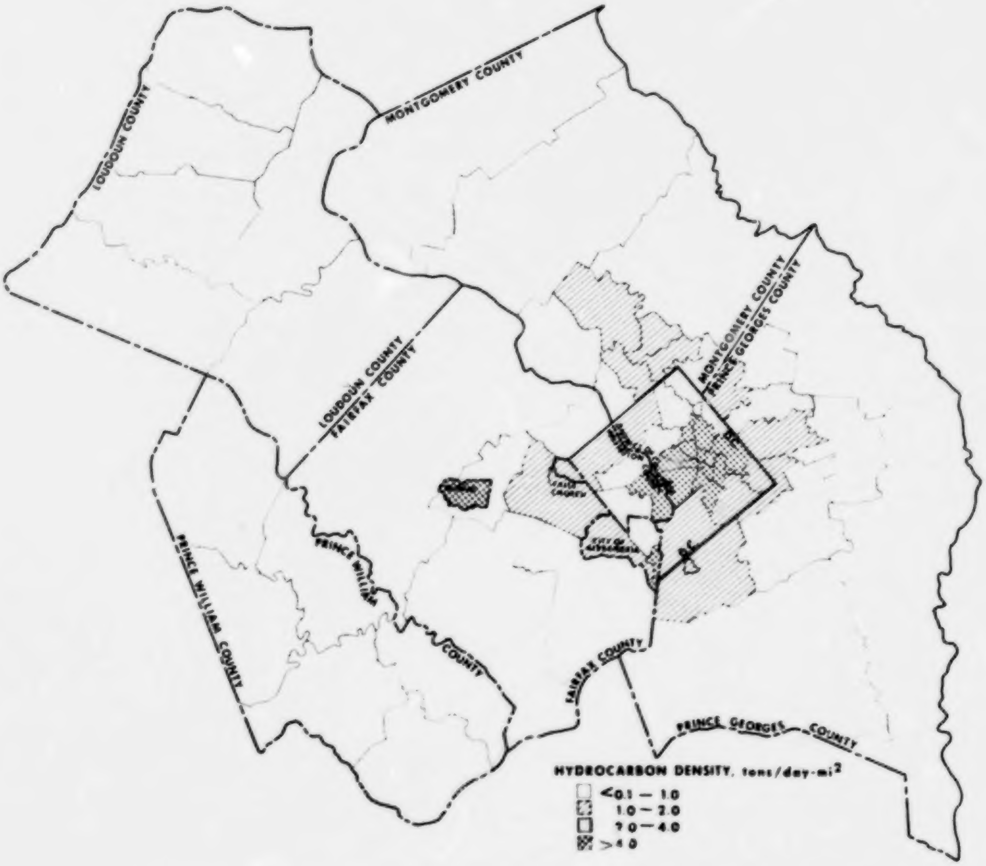
MONTGOMERY COUNTY
LOUDOUN COUNTY
LOUDOUN COUNTY
FAIRFAX COUNTY
MONTGOMERY COUNTY
PRINCE GEORGES COUNTY
PRINCE WILLIAM COUNTY
PRINCE WILLIAM COUNTY
FAIRFAX COUNTY
PRINCE GEORGES COUNTY
CITY OF ALEXANDRIA
D.C.
HYDROCARBON DENSITY, tons/day-mi²
<0.1 — 1.0
1.0 — 2.0
2.0 — 4.0
>4.0

Figure 32. Hydrocarbons emission densities for an average space-heating day.

The average temperature at National Airport was 0.6 degree below normal for the period January through July 1967. January was warmer than normal, and February and May were colder than normal. Daytime cloudiness was well above normal; most months exhibited fewer clear days and more cloudy days than normal. This was especially true of July, which had no clear days and 10 more cloudy days than normal. The average wind speed for the period was 0.6 mile per hour below normal. This decrease was due primarily to an increase in the occurrence of wind speeds between calm and 12 miles per hour, and an equal decrease in those greater than 12 miles per hour.

Each of the above elements, temperature, cloudiness, and wind speed, was tested with a chi-square test to determine whether the monthly average for the sampling period differed significantly from normal. The tests were made at a confidence level of 0.95. For the selected confidence level temperature and wind speed did not differ significantly from the climatological expectancy, although there were a few months that differed from normal as indicated above. Other months were almost exactly normal; therefore, the period as a whole was close to the climatological mean. Daytime cloudiness, however, did not meet the climatological expectancy for the 0.95 confidence level. The failure was due to the very large departure from normal in July and smaller departures in other months.

The frequency of the various wind directions during the study period are shown in the wind rose in Figure 33. Figure 34 is a wind rose for the 10-year period from

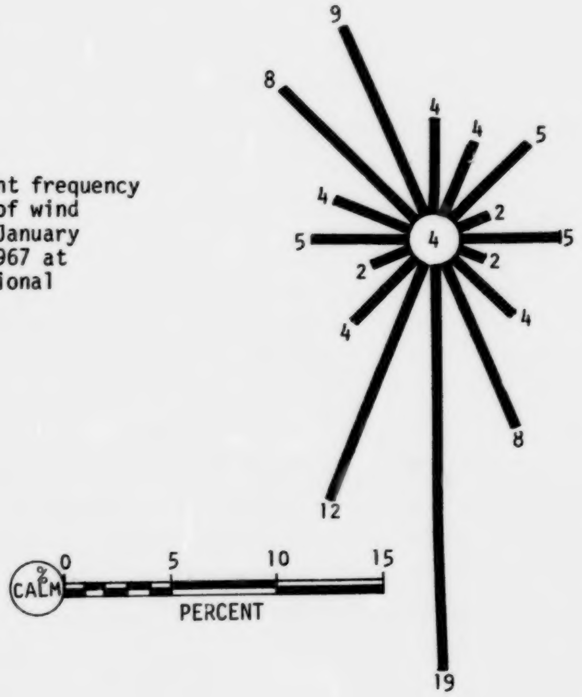

Figure 33. Observed percent frequency of occurrence of wind direction for January through July 1967 at Washington National Airport.

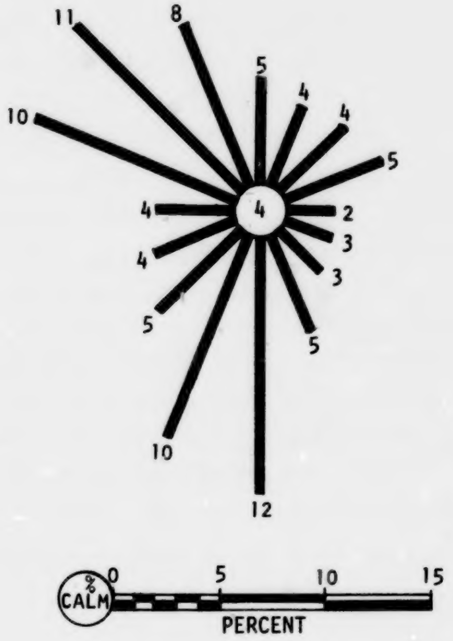

Figure 34. Expected percent frequency of occurrence of wind direction for January through July at Washington National Airport.

1951 through 1960. These roses indicate that during the sampling period there was a marked increase in southeasterly through southerly winds and a decrease in westerly and northwesterly winds.

Vertical temperature measurements are available for three sites in the Washington, D. C., area. There are 300-foot towers at Silver Hill and Tysons Corner. Temperatures are measured at the surface, and at the 100-, 200-, and 300-foot levels. At Dulles International Airport, standard Weather Bureau radiosonde observations are currently made twice a day and are available for a 3-year period, 1960-1962. Also radiosonde data from Silver Hill are available for the period 1957-1959. These temperature data were analyzed for the occurrence of inversions during the winter, spring, and summer months of the study period and compared to the seasonal 1960-1962 and 1957-1959 averages. As shown in Table 49, the frequency of inversions at Tysons Corner was very near the 1960-1962 averages at Dulles and the inversion frequency at Silver Hill was near the 1957-1959 average for the winter months and above average during the spring and summer.

Table 49. PERCENT FREQUENCY OF OCCURRENCE OF ALL INVERSIONS IN STUDY AREA

		Winter	Spring	Summer
Dulles International Airport (radiosonde)	1960-1962	40	29	31
Silver Hill Tower (temperature)	1967	34	32	30
Tysons Corner Tower (temperature)	1967	38	26	--
Silver Hill (radiosonde)	1957-1959	37	26	25

These data indicate that during the winter portion of the study period there was little change from the average in inversion frequency over the area as a whole; however, during the spring and summer months there was a slight increase of inversion frequency in the semi-urban areas.

The potential effects of the variations from normal wind directions and speed upon the distribution of contaminants were ascertained by calculating a theoretical frequency of occurrence of an arbitrary concentration level of some hypothetical pollutant. Wind direction frequencies that actually occurred during the sampling period and wind directions that are normal for January through July were used. The hypothetical sources used in this analysis are at eight points distributed in the cardinal compass directions and at distances of 2 and 9 kilometers from the CAMP sampling site. Rates of emission chosen are directly related to known NO_x emissions that would be coming from sources in the various quadrants and centered at the 2- and 9-kilometer distances from the CAMP sampling station. Further assumptions are: (1) all sources emit the pollutant at a height of 30 meters; (2) only neutral atmospheric stability occurs; (3) vertical dispersion is limited to 900 meters; (4) emissions are constant throughout the 7-month period.

The results of these theoretical calculations are presented in Figures 35 and 36. These figures are for the sampling period and for normal climatological conditions, respectively. They indicate the frequency with which various portions of the Washington, D. C., area could experience an arbitrary concentration level of a hypothetical pollutant. This pollutant is similar to NO_x in its distribution and amount of emissions. The most obvious difference between these figures is the increase during the study period in the frequency of occurrence over the northeast portion of the District of Columbia.

To further delineate differences, Figure 37 was constructed; it demonstrates the departure from normal of the frequency pattern during the study period. General increases in the frequency of occurrence of measurable concentrations over the northeast, east-central, and southeast portions of the study area are clearly evident. These departures from normal are due to the marked increase in the number of southerly winds during the study period. Also, a slight decrease in the

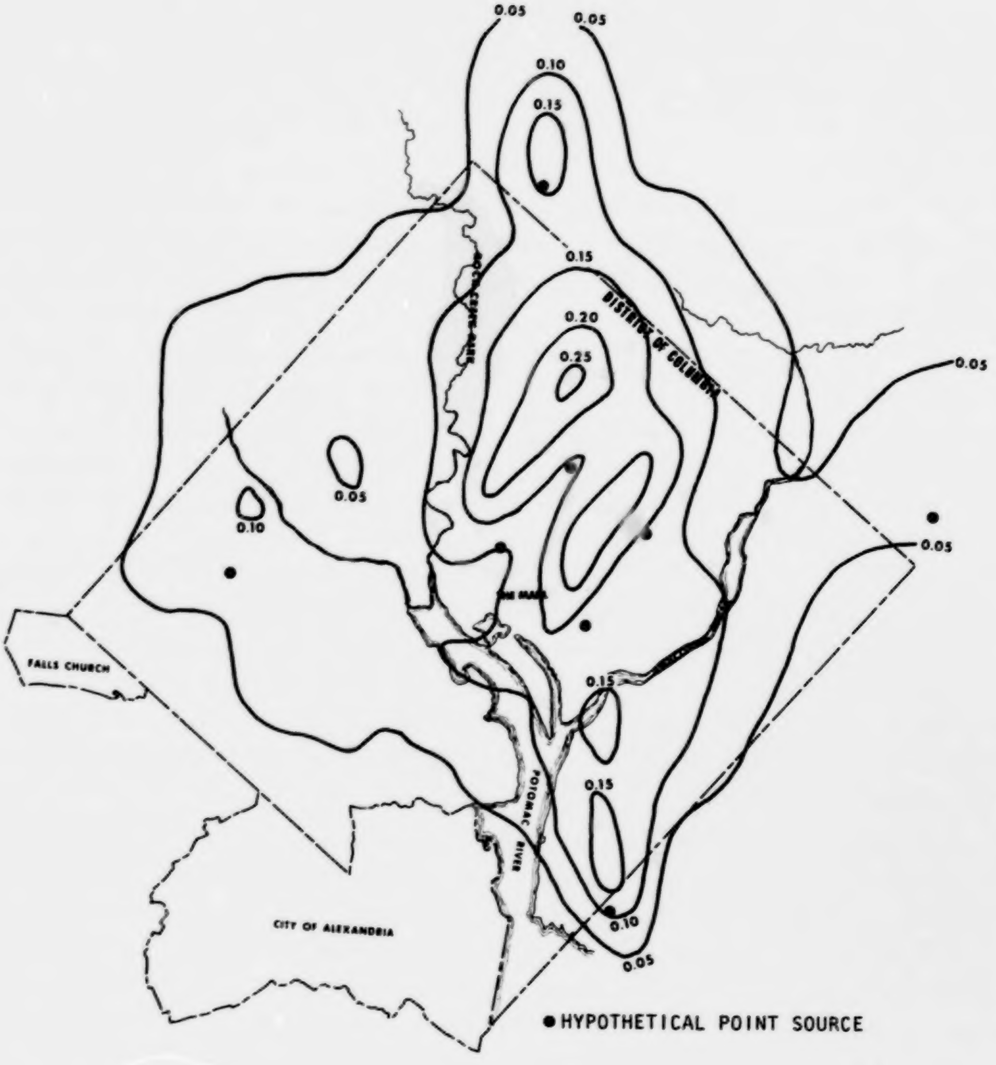
0.05
0.05
0.10
0.15
0.15
ROCK CREEK PARK
DISTRICT OF COLUMBIA
0.20
0.25
0.05
0.05
0.10
0.05
THE MALL
FALLS CHURCH
0.15
0.15
POTOMAC RIVER
CITY OF ALEXANDRIA
0.10
0.05
● HYPOTHETICAL POINT SOURCE

Figure 35. Theoretical percent frequency of occurrence of an arbitrary concentration level of some hypothetical pollutant similar to NO_x. Based on eight symmetrically distributed point sources and on Washington National Airport wind rose for period January - July 1967.

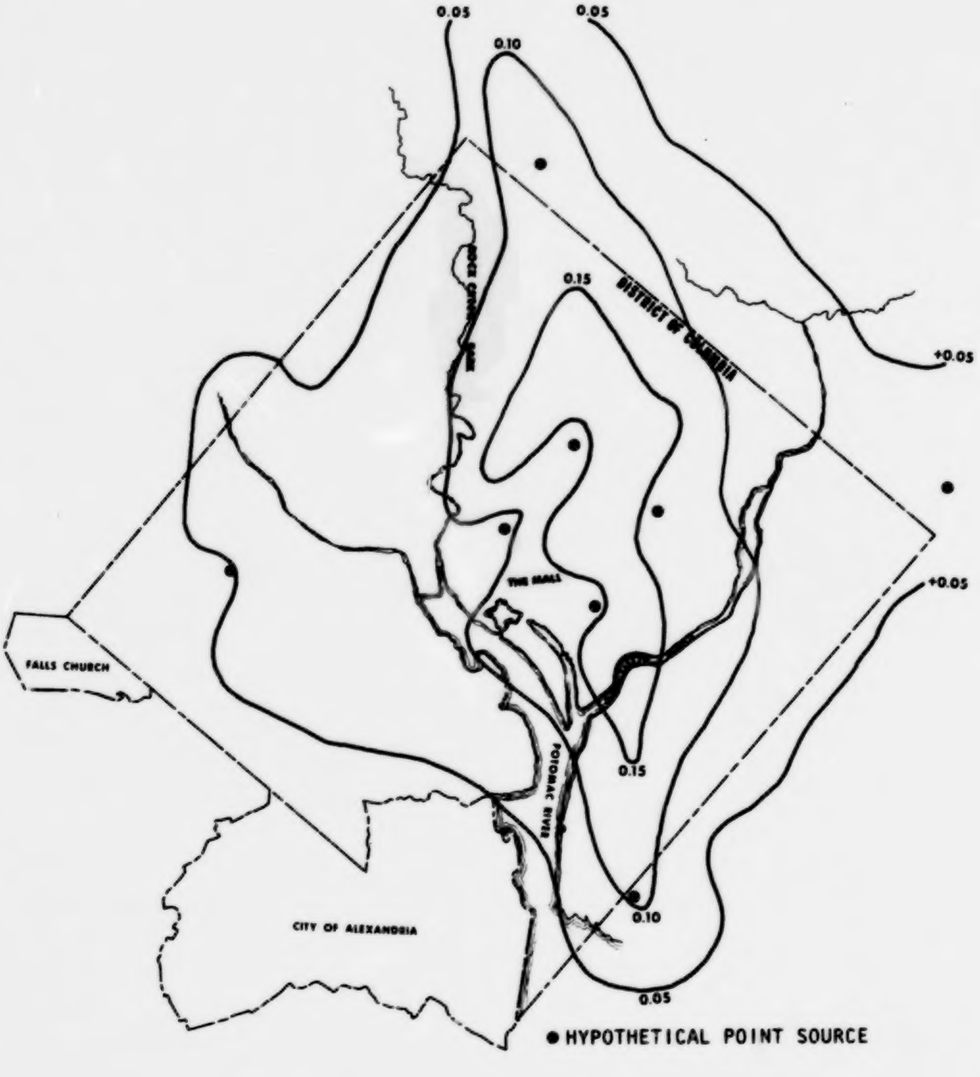
0.05
0.05
0.10
0.15
DISTRICT OF COLUMBIA
ROCK CREEK PARK
+0.05
THE MALL
+0.05
FALLS CHURCH
POTOMAC RIVER
0.15
CITY OF ALEXANDRIA
0.10
0.05
● HYPOTHETICAL POINT SOURCE

Figure 36. Theoretical percent frequency of occurrence of an arbitrary concentration level of some hypothetical pollutant similar to NO_x. Based on eight symmetrically distributed point sources and on the Washington National Airport wind rose for January - July during 1951-1960.

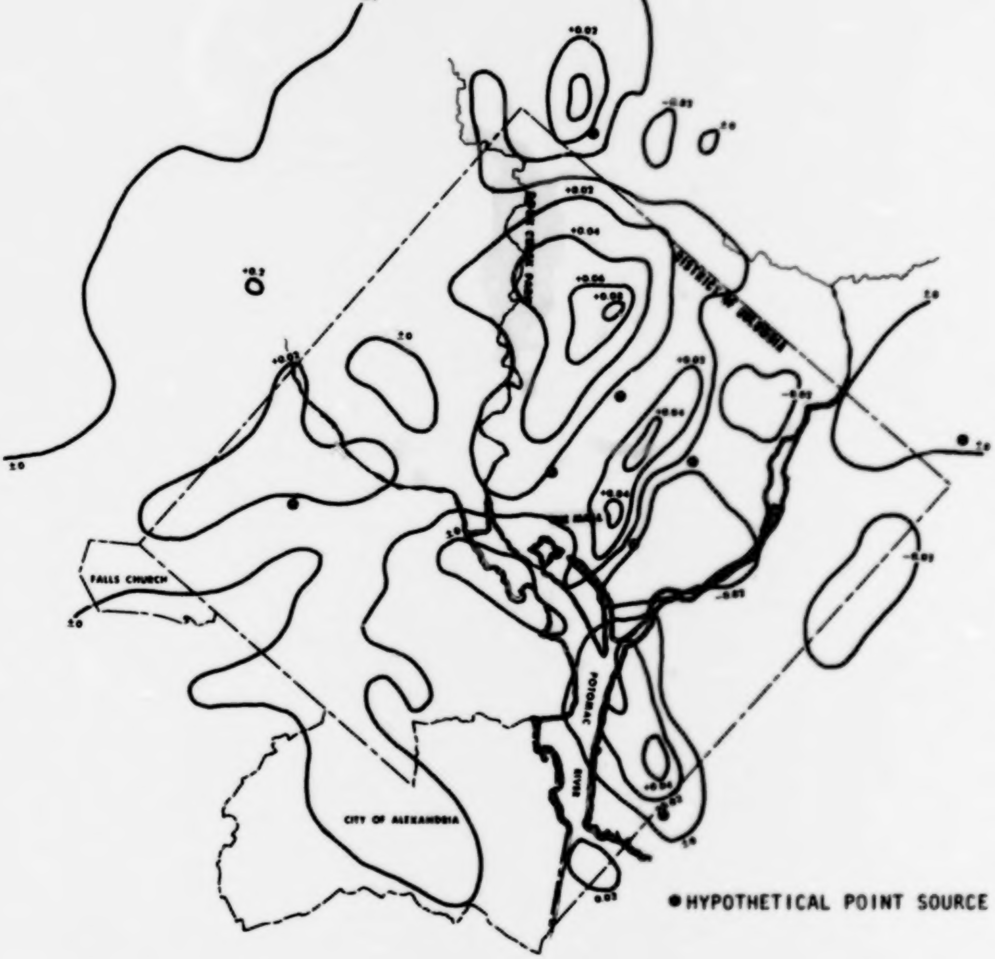
±0
+0.02
−0.02
+0.04
+0.06
+0.08
+0.2
DISTRICT OF COLUMBIA
FALLS CHURCH
CITY OF ALEXANDRIA
POTOMAC RIVER
● HYPOTHETICAL POINT SOURCE

Figure 37. Difference chart; demonstrating departure of theoretical frequency of occurrence of pollutant concentrations during study period from what would normally be expected.

frequency of occurrence over the eastern part of the study area can be seen; this decrease is associated with fewer westerly and northwesterly winds. Southwest and northwest Washington, D. C., show little change from normal as would be expected, since there was little departure from normal in the number of northerly and easterly winds.

The combination of slightly cooler temperatures and lower wind speeds along with increases in daytime cloudiness and semi-urban inversion frequencies indicates a small but definite trend toward less atmospheric dispersion during the sampling period. This trend toward less dispersion indicates the possibility that concentrations measured during the first half of 1967 over the Washington, D. C., area may be slightly higher than the average for the normal January through July period. The frequency of occurrence analysis further indicates the possibility of an increase in the occurrence of measurable pollutant concentrations in the portion of Washington just to the east of a bisecting north-south line. A simultaneous decrease over the eastern portion of the District of Columbia would also be expected for the study period.

V. SPECIAL INVESTIGATIONS

SPECIAL SO_2 SAMPLING

Ambient levels of sulfur dioxide in the Washington metropolitan area are less than those in many other east coast metropolitan areas. It is highly likely, however, that there are areas within the metropolitan area that experience higher sulfur dioxide levels than are observed at the established sampling stations. In order to determine whether the established sampling stations do provide data that are generally typical for the area, and to assess somewhat the impact of emissions from individual sources, mobile SO_2 sensors were installed in automobiles and a series of traverses were made in areas of the city somewhat distant from the fixed sampling stations.

Two periods of sampling were undertaken: May 4-18 and July 24-27, 1967. The first period was selected so as to obtain data before the government heating plants markedly decreased operation for the summer. The second period was chosen when peaking operations of the in-city power plants were likely.

Two mobile electroconductivity samplers, developed for the Geographical Sciences Laboratory, New York University, and used by them under their Public Health Service grant for an urban dynamics study of New York City, were borrowed. During the second sampling period, equipment was rented from Sign X Laboratories, Inc., the developer and producer of the original NYU-owned equipment.

The electroconductivity sensor uses deionized water as a reagent and is subject to interference by CO_2. To estimate the impact of CO_2 on the indicated contamination levels, ambient air was passed through a water impinger at frequent, but not fixed, time intervals before it entered the sensor. The impinger solution absorbed essentially all of the SO_2; the read-out therefore indicated the degree of CO_2 interference. An appropriate calibration curve based on the CO_2 levels was used to evaluate ambient SO_2 concentrations.

The objective was to determine where SO_2 was most prevalent. No fixed sampling pattern was established, but a general pattern was followed. During the May period, the first traverse of the day was an attempt to sense SO_2 trapped by an inversion, if any. Samples were regularly taken on the grounds of the Washington Cathedral. This point is within a few feet of being the highest point in Washington. If an inversion was trapping significant amounts of SO_2, it was reasoned that SO_2 was as

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likely to be detected at this point as any point in the Washington area. As soon as the wind speed increased or cumulus clouds appeared, indications that the lowest-level inversion had dissipated, sampling was undertaken in the vicinity and downwind of suspected SO_2 sources.

The July sampling period was conducted during a period when power needs for air conditioning would be great; therefore, the sampling was primarily during late morning and afternoon.

The May period of sampling was characterized by unseasonably cool, cloudy, and rainy weather. Wind speeds were slightly stronger than expected for May. The July period was warmer and slightly cloudier than normal and was without measurable rain. The wind speed averaged less than normal, but one sampling day was the windiest of the month and another, the calmest. Weather conditions were judged to be conducive for the excellent diffusion of contaminants. Even the day with the least wind was sunny and hot, with scattered cumulus clouds. During weather of this type, pollutants are stirred and mixed through a deep layer, and ground-level concentrations averaged for an hour or more are normally low.

The mobile sampling time totaled 75 hours and 19 minutes. All data were reduced to 5-minute averages to provide appropriate spatial resolution of SO_2 distribution. The findings are summarized in a brief descriptive statement for each day.

May 4, 1967

Sulfur dioxide was below detectable levels on the grounds of Washington Cathedral from 0610 to 0845 EST and to the southeast through Georgetown to the vicinity of the Washington Monument from 0910 to 0942 EST. Along Independence Avenue from 7th Street and 14th Street, N.W., between 0942 to 1000 EST, sulfur dioxide concentrations averaged 0.06 ppm. Sampling was continued downwind of the Central Heating Plant in the Department of Agriculture parking lot on the north side of Independence Avenue between 12th and 14th Streets, S.W., from 1000 to 1124 EST. Dramatic increases in sulfur dioxide were detected. Between 1000 and 1100 EST, sulfur dioxide averaged 0.23 ppm, with a 5-minute average of 0.76 ppm and instantaneous peaks of 1.51 ppm. From 1100 to 1124 EST, the average was 0.30 ppm, with 5-minute peaks of 0.54 ppm and instantaneous peaks of 1.06 ppm.

During the afternoon, sampling was conducted at the marina south of National Airport and downwind of the Potomac River Power Plant. Concentrations averaged 0.05 ppm with one 5-minute average of 0.18 ppm and an instantaneous peak of 0.42 ppm

May 5, 1967

Sulfur dioxide averaged 0.06 ppm between 0700 and 0813 EST at Washington Cathedral. Levels increased gradually to 0.16 to 0.18 ppm from Washington Cathedral to the Agriculture Building via Wisconsin Avenue, Pennsylvania Avenue, 23rd Street, N.W., and Constitution Avenue, between 0813 and 0843 EST. From 0843 to 1000 EST, the average concentration at 12th and Independence Avenue, S.W., was 0.16 ppm. Between 1000 and 1023 EST, it dropped to 0.07 ppm. Peak values reached 0.30 ppm near the Agriculture Building.

From 1029 to 1414 EST, sampling took place within four blocks of M and South Capitol Streets. Hourly averages ranged from 0.06 to 0.13 ppm; 5-minute averages reached as high as 0.28 ppm; and shorter-term peaks reached 0.78 ppm.

May 6, 1967

With southerly flow early in the day, barely detectable levels of SO_2 were found at Washington Cathedral, but averaged 0.08 ppm between 0725 and 0850 EST to the north of Sheridan Circle and through Georgetown. The lack of peaks of consequence indicated that the contaminant was well mixed in the ambient air.

Sampling performed in Alexandria, south of the Potomac River Power Plant, between 1129 and 1154 EST detected no SO_2. From 1204 to 1600 EST, the sampling team set up a station in the vicinity of the Pennsylvania Railroad yards, about 500 feet southwest of the Central Heating Plant at the intersection of 13th and D Streets, S.W. Extremely high concentrations, listed in Table 50, were observed.

Table 50. SULFUR DIOXIDE LEVELS NEAR RAILROAD YARDS
(SO_2, ppm)

Time period	60-min mean	Max. 5-min mean	Peak concentration
1200 - 1300	0.60	1.18	1.42
1300 - 1400	0.40	0.68	1.14
1400 - 1500	0.49	0.94	1.36
1500 - 1600	0.11	0.36	0.68

No significant amounts of SO_2 (60-minute average <0.02 ppm) were found at Hains Point from 1600 to 1715 EST, although short-term peaks up to 0.24 ppm were detected.

May 8, 1967

Sampling was begun at 0710 EST near 11th and Independence Avenue, S.W., continued into Virginia via the Washington Parkway, to the sailing marina, then back into southwest Washington to St. Elizabeth's Hospital and the U. S. Naval Station. In the vicinity of M and South Capitol Street, from noon to 1255 EST, concentrations were quite uniform and averaged near 0.05 ppm. The highest concentrations were near St. Elizabeth's Hospital.

Between 1255 and 1529 EST, samples were collected northwest of the Central Heating Plant along Independence Avenue between 10th and 12th Streets, S.W. Some very high concentrations were detected and are listed in Table 51.

Table 51. SULFUR DIOXIDE LEVELS AT INDEPENDENCE AVENUE BETWEEN 10th AND 12th STREETS
(SO_2, ppm)

Time period	Period mean	Max. 5-min mean	Peak concentration
1255 - 1400	0.46	1.08	1.48
1400 - 1500	0.26	0.72	1.40
1500 - 1529	0.42	1.06	1.42

May 9, 1967

Sulfur dioxide concentrations between 0747 and 0827 EST averaged 0.08 on the Washington Cathedral grounds and in the area eastward to Rock Creek Park. Negligible amounts of contamination were found along 23rd Street, N.W., between P Street and Lincoln Memorial. At 9th and D Streets, S.W., hourly mean concentrations were 0.41 ppm between 0935 and 1031 EST. A 5-minute mean of 0.66 ppm was detected. The peak value was 1.46 ppm.

Between noon and 1430 EST a slow traverse was made through southwest Washington, past National Airport, through Alexandria, across Woodrow Wilson Bridge, and northward to St. Elizabeth Hospital's farm. Most 5-minute values were 0.04 ppm or less. Two values of 0.22 and 0.20 ppm were detected at the U. S. Naval Air Station.

May 10, 1967

Two sensors were operated on this day. Both began the day's sampling at Washington Cathedral between 0632 EST and 0714 EST. Each was driven to the U. S. Naval Air Station: the first via Wisconsin Avenue, 23rd Street, Constitution Avenue, Canal Street, and South Capitol Street Bridge; and the second via Massachusetts Avenue, 23rd Street, Constitution Avenue, Canal Street, and South Capitol Street. Barely detectable levels of SO_2 were found (0.02 ppm or less) except along Massachusetts Avenue between Wisconsin Avenue and 23rd Street. The 15-minute average from 0719 to 0734 EST on this route was 0.13 ppm.

Both mobile sensors sampled simultaneously on C Street between 3rd and 4th Streets (in the parking area between HEW North and HEW South) between 0913 and 0942 EST. Each recorded SO_2 concentrations at 0.01 ppm, which were barely detectable with the electroconductivity sensor. One sensor was kept at the HEW location. Most levels were below detectable levels except that concentrations of 0.10 ppm were sensed near 1000 EST for a half hour and near 1230 EST for 10 minutes.

The second sensor made a traverse through southwest Washington to St. Elizabeth's Hospital, back to southwest Washington, along Interstate 95, and past National Airport to the sailing marina. No 5-minute concentration exceeded 0.02 ppm.

This day was particularly clean with respect to SO_2, with the only significant SO_2 levels being reached along Massachusetts Avenue.

May 11, 1967

From 0638 to 0743 EST, 0.04 ppm was sensed at Washington Cathedral. From 0829 to 0909, 0.03 ppm was detected between the 14th Street Bridge and Alexandria along the Washington Memorial Parkway and U. S. Route No. 1.

May 17, 1967

A 30-minute sample in mid-afternoon was made at the National Arboretum. The SO_2 concentration was less than 0.02 ppm.

May 18, 1967

A 2-hour sample was made to the northeast of Kenilworth dump at Quarles and Anacostia, N.E., or in the general vicinity of the intersection. Hourly mean concentrations were 0.04 ppm. The greatest 5-minute mean value was 0.08 ppm. The highest instantaneous peak was 0.10 ppm. These consistent values indicated that the SO_2 was unusually evenly distributed in the ambient air.

July 24, 1967

This day was the first of a 4-day period when a sampling program was conducted to determine the likely greatest impact of the in-city power plants on Washington's SO_2 environment. The period was hot. Maximum temperatures exceeded 89° F every day. It was reasonable to expect that power demands for air conditioning would be great and that in-city power plants would be operating at greater than average values. Plumes were carefully observed, and conscientious attempts were made to locate the sampler downwind and at an appropriate distance from a probable source where ground-level concentrations would be maximum. Total sampling time was 21 hours and 40 minutes.

Concentrations sensed in southwest Washington, the sailing marina, and along U. S. Route No. 1 south of the Pentagon were below detectable levels, although very short-term peaks of 0.10 ppm were observed occasionally.

July 25, 1967

No significant levels were found on a traverse from the Capitol, Washington Monument, U. S. Route No. 1 to Interstate 495, Woodrow Wilson Bridge, Interstate 295, and the Aquatic Gardens. The slow traverse encompassed the period from 1045 to 1325 EST.

From 1350 to 1835 EST, sampling was conducted at the National Arboretum, Aquatic Gardens, Bladensburg, Cheverly, then south along Interstate 295 to the Woodrow Wilson Bridge. A few 5-minute periods of detectable levels of SO_2 were sensed; 0.04 ppm in the Arboretum and 0.09 in the Aquatic Gardens were the highest. Overall hourly averages were less than 0.01 ppm.

July 26, 1967

When sampling was started at 0845 EST, an inversion was still apparent in the vicinity of the river. A slow traverse was made through Alexandria, across Woodrow Wilson Bridge, and north along Interstate 295 to U. S. Naval Station. Significant concentrations of SO_2 were detected between Woodrow Wilson Bridge and the Naval Research Laboratory. The hourly average was 0.06 ppm, with a 5-minute average reaching 0.16 ppm and a peak reaching 0.25 ppm.

From 1105 to 1205 EST, the sampler was operated at the U. S. Naval Air Station within 50 feet of the location of the fixed sampler. The hourly average concentration was 0.02 ppm compared to the fixed sampler's 0.03 ppm for the same period.

July 27, 1965

Beginning at 0805 EST, a traverse through Alexandria, across Woodrow Wilson Bridge, and north on Interstate 295 was again made to detect SO_2 when an inversion prevailed over the river. The average 1-hour concentration was 0.05 ppm; the maximum 5-minute average, 0.11 ppm; and the maximum instantaneous peak, 0.18 ppm.

From 1020 to 1115 EST, a slow traverse was made from U. S. Naval Station to Silver Spring, Maryland, via Constitution Avenue and 16th Street. Five-minute mean concentrations were 0.06 to 0.10 ppm in downtown Washington and dropped below the detectable level near Silver Hill.

From 1250 to 1640 EST, a slow traverse with frequent stops was made from Silver Spring, Maryland, along Eastern Avenue to the National Arboretum, Aquatic Gardens, Naval Research Laboratory, Woodrow Wilson Bridge, and north on Route No. 1 to near the Pentagon. No significant values of SO_2 were detected, although instantaneous peaks up to 0.12 ppm were noted passing the Benning Power Plant, Bolling Field, and near the Potomac Railroad yards.

From the results of these sampling efforts it is concluded that there are areas within the Washington metropolitan area where sulfur dioxide concentrations reach levels that should cause immediate concern. The most significant one is in the vicinity of the Central Heating Plant. The stacks of the plant are essentially the same height as the surrounding buildings. As a result, when winds of modest strength occur, turbulence created by the building complex causes aerodynamic downwash of the plume as described by Halitsky.[18] Very high concentrations of sulfur dioxide are observed occasionally. (See discussion on Agriculture Building sampling.)

Enough sulfur dioxide was detected in the vicinity of Woodrow Wilson Bridge to suggest strongly that interstate transport of sulfur dioxide occurs. On the morning of July 26 and 27, 1967, during a noticeable inversion and light northerly drift, hourly averages reached 0.05 ppm.

No significant levels of sulfur dioxide that might definitely be attributed solely to an in-city power plant were detected. The weather was ideal for dispersing plumes. Sampling was conducted during periods of great instability because under such conditions maximum concentrations from elevated sources occur near the source. No problem of identifying the source would be encountered if significant levels of SO_2 were encountered.

Data acquired with the mobile sampling equipment were in good agreement with data acquired by fixed-station sensors.

SOURCE TESTING

As part of the on-site investigations in the Washington, D. C. area, personnel of the Abatement Program conducted tests for atmospheric emissions from a number of Federal and private combustion and incineration units. Particulate emissions were measured at each unit tested; in addition, sulfur and nitrogen oxide emissions were measured at some of the installations.

Combustion Unit Tests

Three coal-burning units owned by the Federal Government were tested. These consisted of a spreader stoker equipped with flyash collection equipment and two underfeed stokers with no flyash control equipment. All of these units burned stoker-sized coal with a heating value of about 14,000 Btu and the following composition:

Component	Weight percent
Moisture	3
Volatile matter	35
Fixed carbon	56
Ash	6
Sulfur	0.7

Three separate tests for particulate emissions were conducted on each coal-burning unit. The average results of these tests are shown in Table 52 and emission data are shown in Figure 38. Actual emissions are compared in Figure 38 with the allowable emissions as specified in the Regulations implementing Executive Order 11282 for Federal Facilities.

The two underfeed stokers were able to meet the Federal emission Regulations except that they did emit particles larger than 60 microns in size. The spreader stoker unit could not meet any of the Federal Regulations, and exceeded both the allowable particulate emissions and the allowable visible emission regulations. This unit was equipped with both a cyclone and an electrostatic precipitator to control flyash emissions and did not reinject any flyash, but the electrostatic precipitator was not working properly and plans were under way to replace this collector.

Particulate emissions from these units would, of course, vary if the type of fuel or the operating conditions varied.

Table 52. AVERAGE PARTICULATE EMISSIONS FROM COMBUSTION UNITS

Type of unit	Fuel type	Emissions,		
		Rate	grains/scf[a]	lb/10^6 Btu
Underfeed stoker	Coal	5.2 tons/hr	0.077	0.25
Underfeed stoker	Coal	0.9 tons/hr	0.043	0.18
Spreader stoker	Coal	1.7 tons/hr	0.15	0.67
Oil burner	Oil	135 gal/hr	0.055	0.15
Oil burner[b]	Oil	80 gal/hr	0.086	0.21

[a] Corrected to 60° F, 29.9in. Hg.

[b] Privately owned.

Two residual fuel oil burning units were also tested, one Government owned and one owned by a municipal school. The fuel burned in these units contained 2.75 percent sulfur. These boilers could meet the particulate and visible emission regulations specified in the Regulations implementing Executive Order 11282.

Table 52 includes the particulate emission data from these two oil-burning units, and for comparison the data are also shown in Figure 38. Nitrogen oxide emissions, calculated as nitrogen dioxide, were found to vary from 12 to 23 pounds per ton of fuel in the coal-burning units, and from 60 to 75 pounds per 1000 gallons of fuel in the oil-burning units. Limited sulfur dioxide analysis indicated that, as expected, over 95 percent of the sulfur in the fuel appeared as sulfur dioxide in the exit gas streams.

Incinerator Tests

Three incinerators were tested as part of this study. One was a local municipal incinerator, and two were smaller commercial-type units operated by the Federal Government and designated as Incinerator No. 1 and No. 2.

The multiple-chamber municipal incinerator was of modern design with a capacity of 300 tons of refuse per day, and was equipped with a wetted-baffle-wall chamber to reduce particulate emissions.

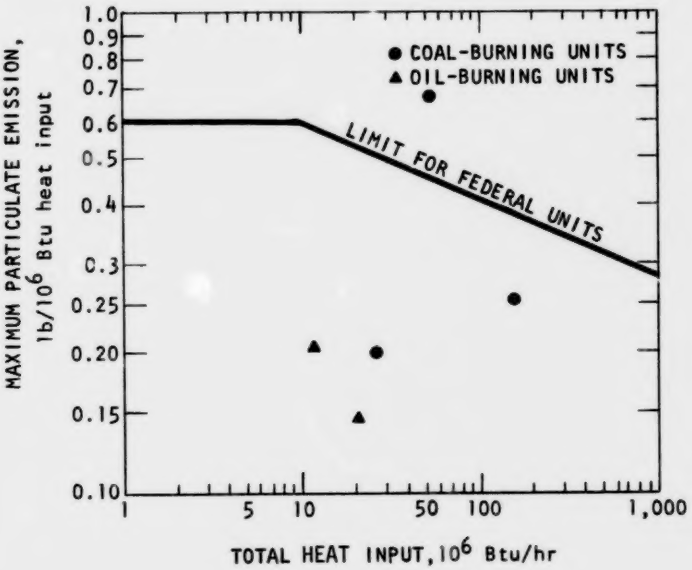


Figure 38. Particulate emissions from combustion sources.

Incinerator No. 1 was a multiple-chamber, top-charged unit rated at 2,500 pounds per hour. This unit burned refuse and paper, and was frequently overloaded. No air pollution control equipment was used.

Incinerator No. 2 was an older unit consisting of three primary burning chambers and a single secondary settling chamber. This unit, rated at about 4,300 pounds per hour, burned largely paper. Average incinerator charging rates and particulate emissions are shown in Table 53.

Table 53. AVERAGE PARTICULATE EMISSIONS FROM INCINERATORS

Unit	Charging rate, tons/hr	Emissions,	
		grains/scf[a]	lb/ton refuse
Municipal incinerator	10	0.26	4.9
Government incinerator No. 1	3.7	0.36	2.6
Government incinerator No. 2	2.7	0.54	15

[a] Standard cubic foot (Corrected to 60° F, 29.9 in. Hg and 12 % CO_2).

Nitrogen oxide emissions from the municipal incinerator averaged 2.5 pounds per ton of refuse, and those from incinerator No. 2 averaged 3 pounds per ton of refuse. No sulfur dioxide measurements were made. All of these units exceed the emission regulations specified in the Regulations implementing Executive Order 11282 for Federal Facilities, and also the regulations promulgated in the Model Air Pollution Ordinance, Metropolitan Washington Council of Governments.

VI. POLLUTION IMPACT ON REGION

ISO-INTENSITY MAPS

Iso-intensity maps were constructed for sulfation, dustfall, and suspended particulate data (Figures 39, 40, and 41). These maps were drawn uning the average concentration values for each station. As would be expected, these iso-intensity lines generally coincide with the results of the emission inventory of sources.

The iso-intensity map for sulfation was briefly discussed in the section on sulfur dioxide air quality data. As noted previously, and as shown in Figure 39, the highest concentrations were centered in an area from northeastern Washington, D.C., to northwest Prince Georges County with subsequently lower levels in a circular pattern about this high-concentration area.

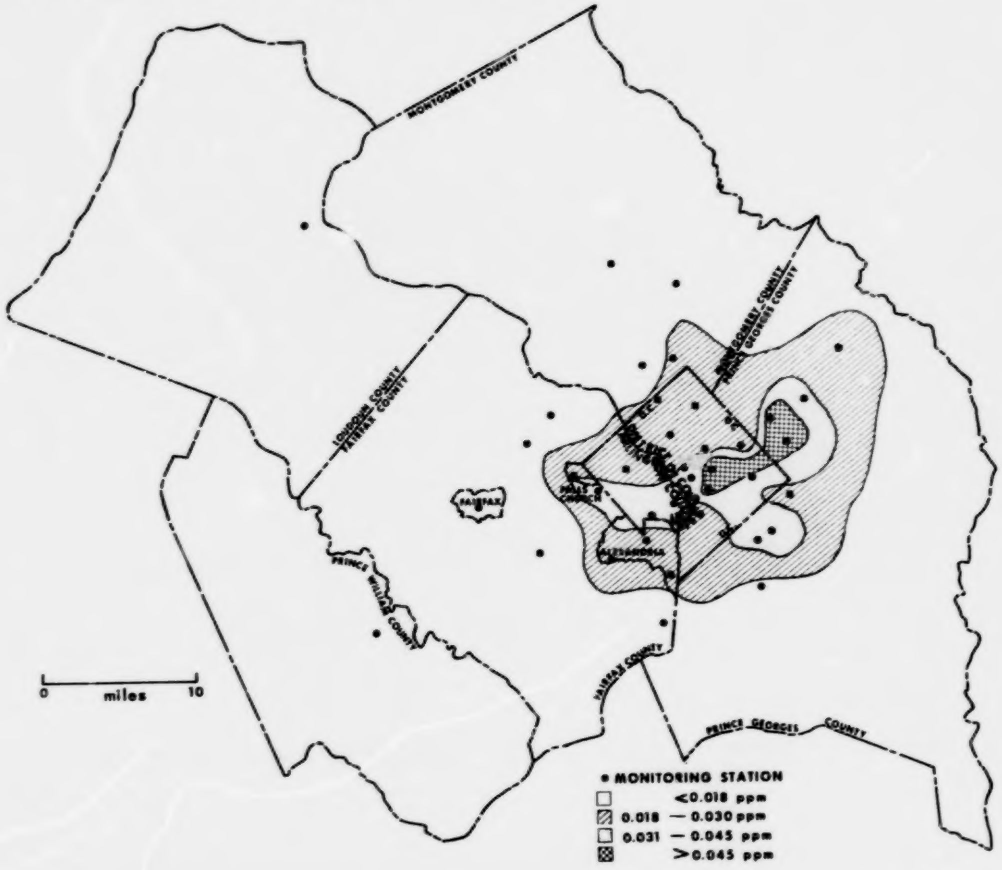

MONTGOMERY COUNTY
LOUDOUN COUNTY
FAIRFAX COUNTY
MONTGOMERY COUNTY
PRINCE GEORGES COUNTY
FAIRFAX
ALEXANDRIA
PRINCE WILLIAM COUNTY
FAIRFAX COUNTY
PRINCE GEORGES COUNTY
0
miles
10
● MONITORING STATION
□ <0.018 ppm
▨ 0.018 — 0.030 ppm
□ 0.031 — 0.045 ppm
▩ >0.045 ppm

Figure 39. Geographic distribution of average monthly SO_2 concentrations derived from sulfation values.

The geographical distribution of suspended particulate values is shown in Figure 40. The highest concentration areas are those immediately adjacent to Kenilworth Dump (Station 65) and the CAMP Station (Station 33). Concentrations in excess of 75 $\mu g/m^3$ extend in a circular pattern of about 5 miles radius from these two center stations. Available data indicate suspended particulate concentrations of less than 75 $\mu g/m^3$ generally are found in the remaining sections of the study area.

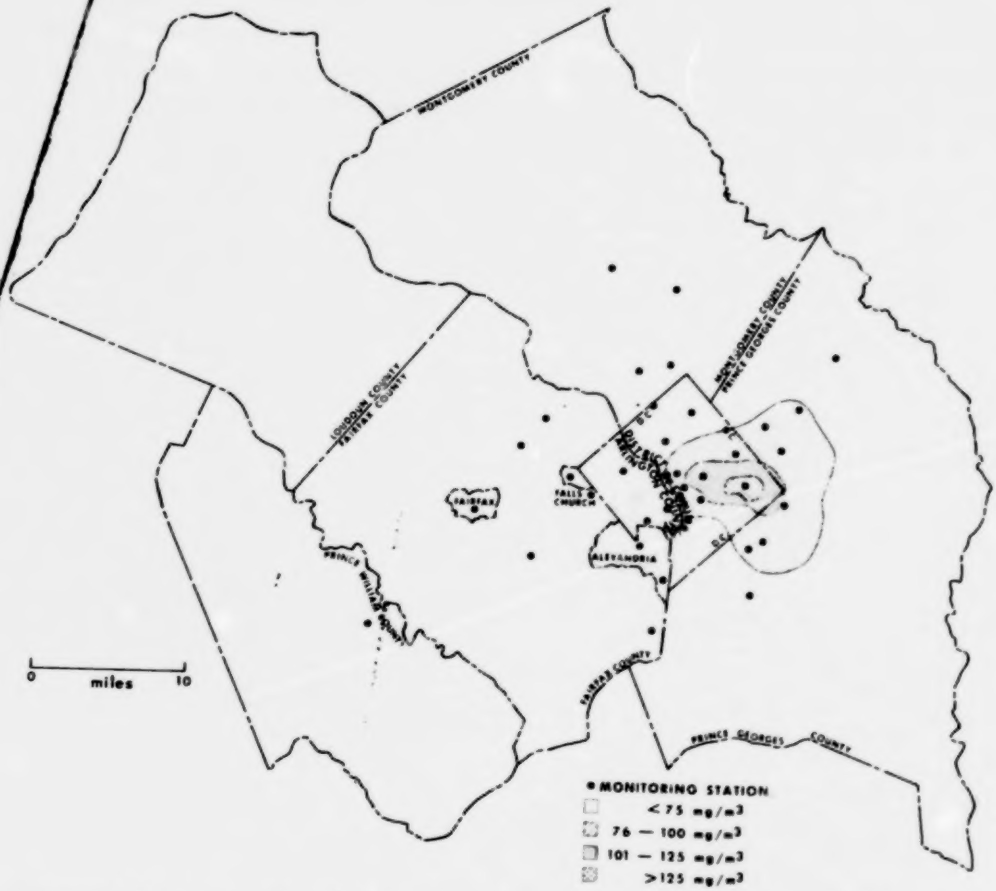

MONTGOMERY COUNTY
MONTGOMERY COUNTY
PRINCE GEORGES COUNTY
LOUDOUN COUNTY
FAIRFAX COUNTY
D.C.
DISTRICT OF COLUMBIA
ARLINGTON
FALLS CHURCH
FAIRFAX
ALEXANDRIA
PRINCE WILLIAM COUNTY
FAIRFAX COUNTY
PRINCE GEORGES COUNTY
0 miles 10
● MONITORING STATION
< 75 mg/m3
76 — 100 mg/m3
101 — 125 mg/m3
>125 mg/m3

Figure 40. Geographic distribution of average monthly suspended particulate concentrations.

The iso-intensity map for settleable particulate (dustfall) shows that the area of highest loadings greater than 30 tons/mi^2-mo, is centered about southern Arlington County. Concentrations greater than 20 tons/mi^2-mo covers a horseshoe-shaped area of about 5 by 8 miles around the above area. Geographic distribution of dustfall greater than 10 tons/mi^2-mo includes all of the District of Columbia proper, Alexandria, Falls Church, and most of Arlington, as well as parts of Prince Georges, Montgomery, and Fairfax Counties.

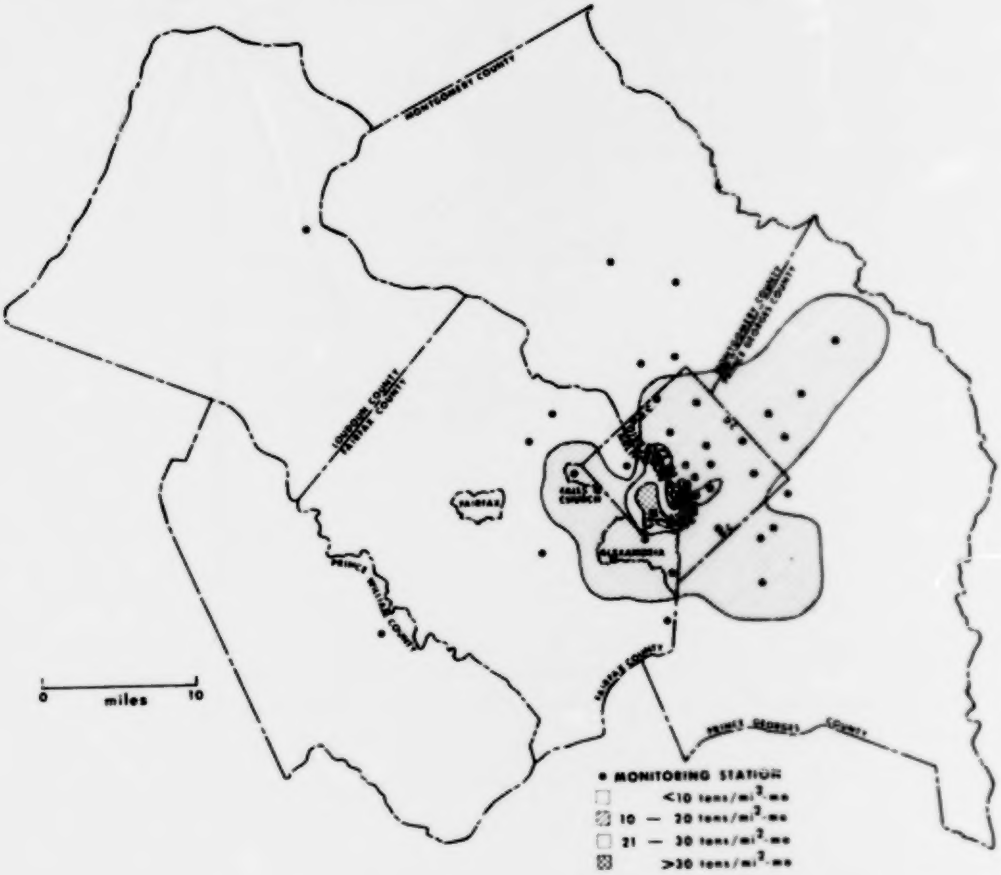
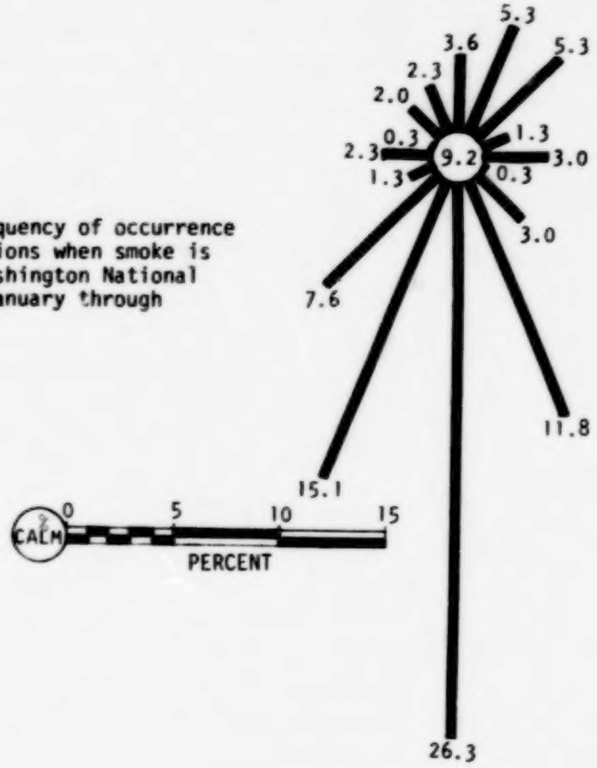

MONTGOMERY COUNTY
LOUDOUN COUNTY
FAIRFAX COUNTY
FAIRFAX
FALLS CHURCH
ALEXANDRIA
MONTGOMERY COUNTY
PRINCE GEORGES COUNTY
PRINCE WILLIAM COUNTY
FAIRFAX COUNTY
PRINCE GEORGES COUNTY
0 miles 10
● MONITORING STATION
<10 tons/mi2-mo
10 — 20 tons/mi2-mo
21 — 30 tons/mi2-mo
>30 tons/mi2-mo

Figure 41. Geographic distribution of average monthly dustfall measurements (arithmetic means).

SMOKE ROSE

A smoke rose relating the occurrence of smoke, smoke and haze, or smoke and fog to wind direction at Washington National Airport is presented in Figure 42. During January through June 1967, 61 percent of the time when smoke occurred in some form, the wind was from a direction south-southeast through southwest. In addition to aircraft operating at or near the airport, there are a number of particulate sources, including open burning and an incinerator in the directions south-southeast through southwest from the airport.

Figure 42. Percentage frequency of occurrence of wind directions when smoke is reported at Washington National Airport from January through July 1967.



Smoke is reported much more frequently at Washington National Airport, which is 3 miles south of the Washington Monument, than at Dulles International Airport, about 22 miles west-northwest of the city. During the sampling period smoke was reported 7 percent of the time at the Washington National Airport and 1 percent of the time at Dulles.

These data indicate that particulate sources to the south and southwest of Washington National Airport are major factors in the occurrence of reduced visibility at the airport.

POLLUTION ROSES

SO_2 pollution roses are depicted in Figures 43 through 47 for five sampling sites in the Washington, D.C., area. These five are: Seven Corners and Alexandria, Virginia; Hyattsville and Cheverly, Maryland; and the U.S. Naval Station. All the roses are for occurrences of measured SO_2 concentrations greater than 0.1 ppm. Seven Corners, Hyattsville, and Cheverly experienced concentrations greater than 0.1 ppm more than 2.5 percent of the time on an hourly basis, whereas Alexandria and the U.S. Naval Station experienced this level less than 1 percent of the time.

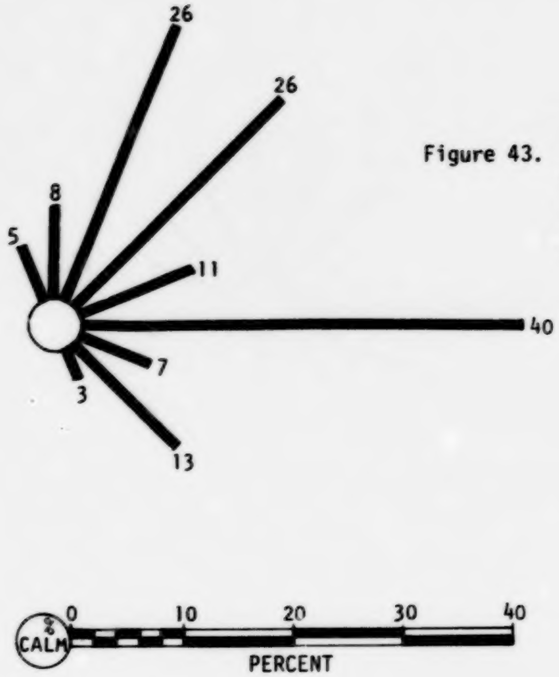


Figure 43. Seven Corners SO_2 Pollution Rose - Percentage of occurrences of wind directions accompanied by SO_2 concentrations >0.1 ppm during February, March, and April, 1967.

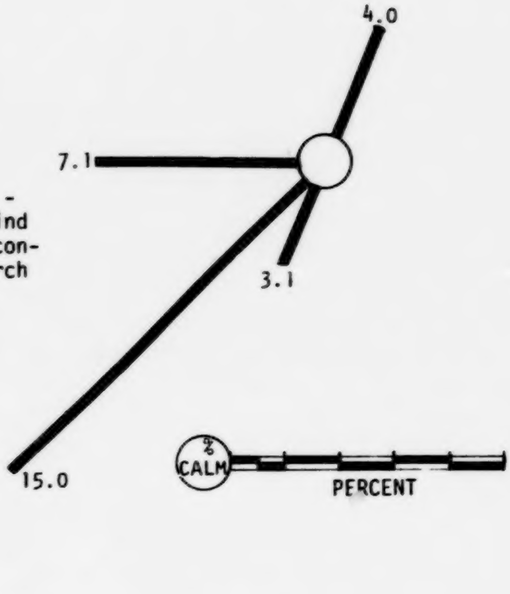
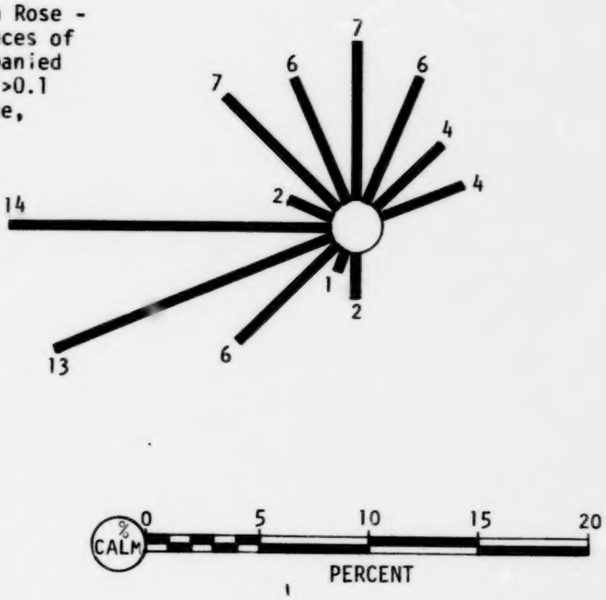


Figure 44. Hyattsville SO_2 Pollution Rose - Percentage of occurrences of wind directions accompanied by SO_2 concentrations >0.1 ppm during March and April, 1967.

Figure 45. Cheverly SO_2 Pollution Rose - Percentage of occurrences of wind directions accompanied by SO_2 concentrations >0.1 ppm during May and June, 1967.



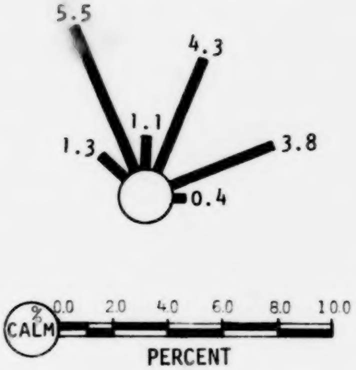


Figure 46. Alexandria SO_2 Pollution Rose - Percentage of occurrences of wind directions accompanied by SO_2 concentrations >0.1 ppm, during March through July, 1967.

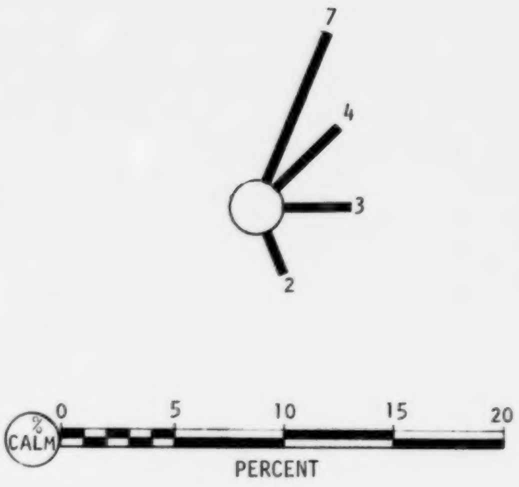


Figure 47. U.S. Naval Station SO_2 Pollution Rose - Percentage of occurrences of wind directions accompanied by SO_2 concentrations >0.1 ppm during May, June, and July, 1967.

The pollution rose for Seven Corners, Virginia, indicates that when easterly winds occur, this area is frequently affected by the large cluster of point sources located around the confluence of the Potomac and Anacostia Rivers. With northeasterly winds, sources west of the Rock Creek Parkway in the District of Columbia also affect this area. The interstate transport of SO_2 is indicated here.

In the vicinity of Hyattsville and Cheverly, southwesterly and westerly winds flowing from the east-central and northeastern portions of Washington, D.C., are frequently accompanied by SO_2 concentrations greater than 0.1 ppm. Also, at times, northerly and northeasterly winds from the directions of the University of Maryland, the U.S. Department of Agriculture, and NASA, and south-southwesterly or southwesterly winds from the direction of the Benning Road Power Plant have a significant impact on the area. These pollution roses again indicate the interstate transport of SO_2.

Although the stations at Alexandria and the U.S. Naval Station recorded hourly concentrations of SO_2 greater than 0.1 ppm less than 1 percent of the time, these concentrations, when they did occur, were associated with certain wind directions. The rose for Alexandria points in the directions of the same sources as did the rose for Seven Corners. At the U.S. Naval Station, winds flowing down the Anacosta River and winds from the direction of St. Elizabeth Hospital at times accompanied SO_2 concentrations greater than 0.1 ppm.

These five pollution roses have indicated that when SO_2 concentrations greater than 0.1 ppm occur, they can usually be associated, through accompanying wind directions, with a specific source or source area. Often interstate transport is involved when the selected concentration level is exceeded.

Roses using the AISI particulate soiling index are shown in Figure 48 through 50 for three sites. These pollution roses are for Coh values greater than 1.0. This Coh value was exceeded 1.6 percent of the time at Alexandria; 2.3 percent of the time at Suitland, Maryland; and 6.8 percent of the time at 1500 Rhode Island Ave. in Northwest Washington, D.C.

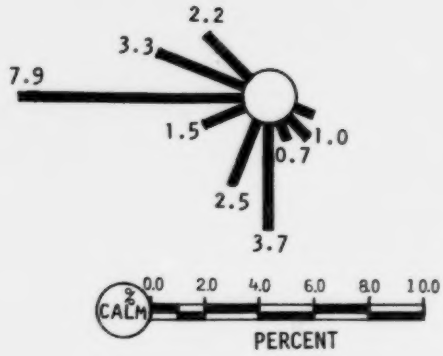


Figure 48. Alexandria AISI Pollution Rose - Percentage of occurrences of wind directions accompanied by COH values >1.0 during April, May, and June, 1967.

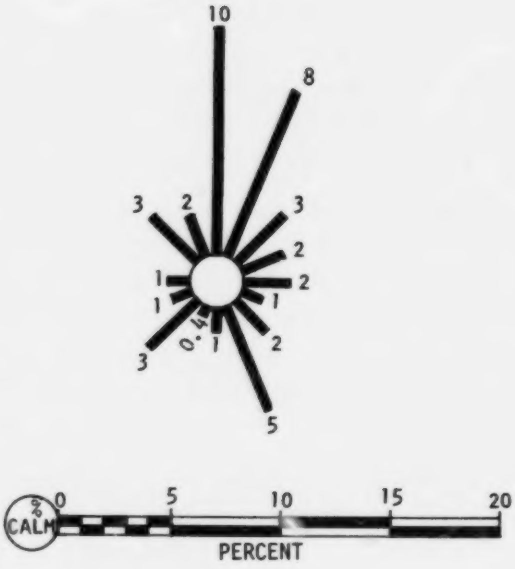
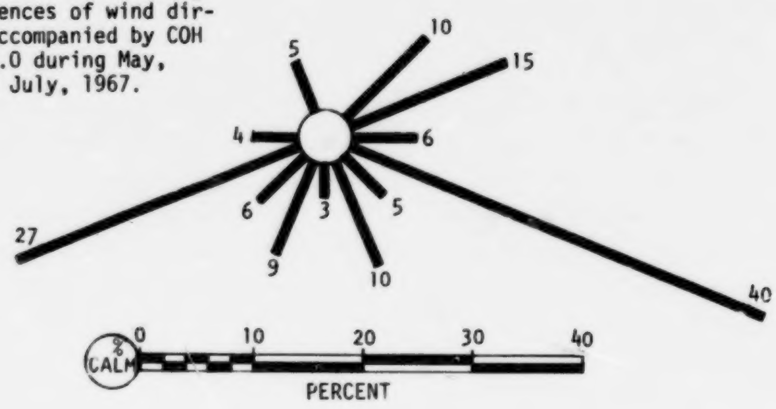


Figure 49. Suitland AISI Pollution Rose - Percentage of occurrences of wind directions accompanied by COH values >1.0 during March through July, 1967.

Figure 50. Rhode Island Avenue AISI Pollution Rose - Percentage of occurrences of wind directions accompanied by COH values >1.0 during May, June, and July, 1967.



The Alexandria AISI pollution rose shows Coh values greater than 1.0 accompanied by westerly winds were notable part of the time. This direction indicates particulates coming from the open-burning dumps and incinerators to the west. The Suitland rose shows that Coh values greater than 1.0 occur most often with northerly, northeasterly, and southeasterly winds. Those with southeasterly winds indicate particulates coming from the direction of Andrews Air Force Base. Those associated with other directions suggest such sources as the Kenilworth Dump and various other point sources.

At the Rhode Island Avenue location Coh values greater than 1.0 occur most frequently with west-southwest and east-southeast winds. Because of the central location of the sampling site, however, association of these values with any of the many possible sources has not been undertaken.

IMPACT OF CENTRAL HEATING PLANT ON SOUTH AGRICULTURE BUILDING

While mobile sampling for SO_2 was being conducted high concentrations were detected in the vicinity of the Agriculture Building near Independence Avenue and 12th Street, S.W. Immediate action was taken to install a portable SO_2 sampler in the building. Data were collected continuously from May 4 to 18, 1967.

A pollution rose (Figure 51) associating wind directions at National Airport with SO_2 levels at the Agriculture Building shows that when concentrations greater than 0.1 ppm were observed, the winds were almost invariably from the southeast clockwise through southwest. During the 2-week sampling period, winds were observed from 150 through 230 degrees for 143 hours, of which simultaneous SO_2 data were available for 140 hours. Precisely half the time (70 hourly occurrences) that these wind directions occurred, SO_2 concentrations at the Agriculture Building exceeded 0.1 ppm, and 29 percent of the time they exceeded 0.25 ppm. When winds were between 150 and 230 degrees, the average SO_2 concentration was 0.25 ppm. When winds were 240 degrees clockwise through 140 degrees, the average concentration was 0.05 ppm.

The association between high SO_2 concentrations and wind direction strongly indicates that the source of the SO_2 was the Central Heating Plant located in the block between C and D Streets and 12th and 13th Streets., S.W. This plant operates from September 15 to June 30. It burns coal and emits an average of 17 tons of SO_2 daily. The rate of emission is quite uniform, with a slight morning peak. The effluent is emitted from stacks 120 feet above ground level, but only 10 feet above the plant's roof. Consequently, the plume is extremely susceptible to aerodynamic downwash in even a light breeze.

While most locations experience maximum concentrations of SO_2 during the morning hours, the greatest concentrations at the Agriculture Building occurred during the mid-afternoon when surface winds are stronger. This is another reason to suspect that aerodynamic downwash is involved. In fact, during May 1967, National Airport winds

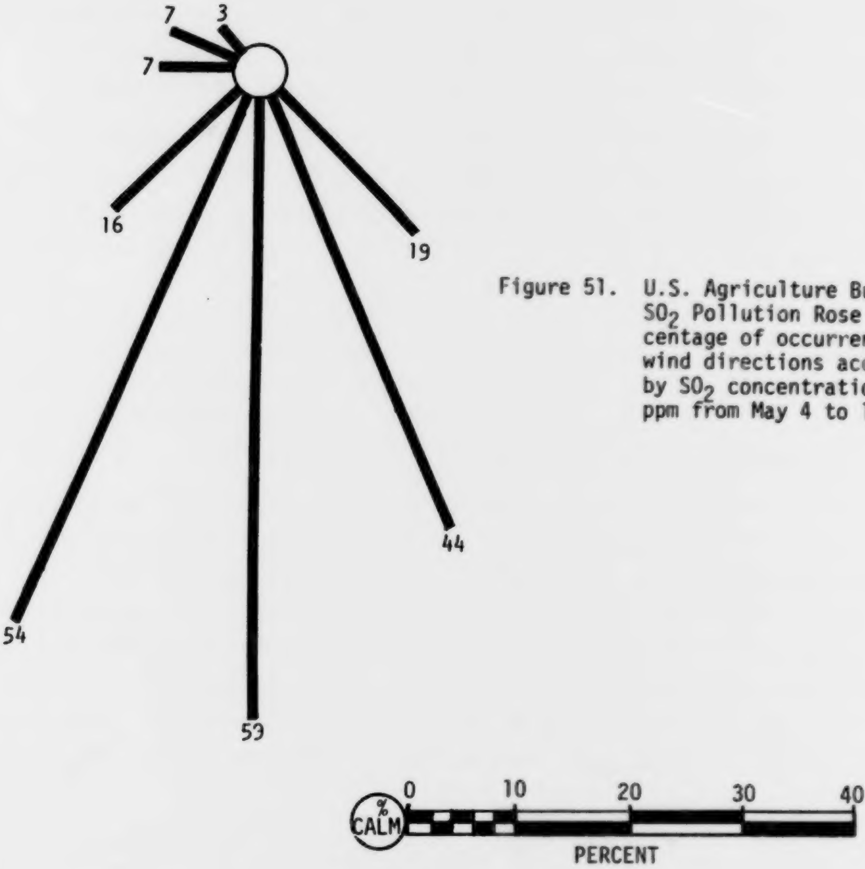


Figure 51. U.S. Agriculture Building SO_2 Pollution Rose - Percentage of occurrences of wind directions accompanied by SO_2 concentrations >0.1 ppm from May 4 to 18, 1967.

averaged 12.4 mph from 1200 to 1600 EST and only 7.6 mph from 0200 to 0600 EST. Considering the hours when wind directions were between 150 to 230 degrees, and simultaneously the SO_2 concentration was greater than 0.1 ppm, it was found that wind speeds were 8 mph or greater 80 percent of the time. If the hourly concentration exceeded 0.25 ppm, 87 percent of the winds were 8 mph or greater. When concentrations were 0.1 ppm or less, the wind equalled or exceeded 8 mph only 40 percent of the time. The critical wind speed for aerodynamic downwash to develop was therefore concluded to be near 8 mph. If the winds were from 150 to 230 degrees with 8-mph speed, it was expected that the effluent from the Central Heating Plant would seriously contaminate the Agriculture Building.

To further explore the impact from this plant, data from the mobile sampling can be examined. On May 6, from 1200 to 1600 EST, samples were collected to the southwest of the heating plant in the Pennsylvania Railroad yards. A northeasterly wind of 13 to 15 mph prevailed throughout the period. Concentrations in the Agriculture Building averaged 0.02 ppm, while concentrations in the railroad yard downwind from the Central Heating Plant averaged 0.40 ppm with hourly averages as high as 0.60 ppm, and 5-minute averages as high as 1.18 ppm.

From 1600 to 1700, May 8, 1967, the wind speed averaged 8 mph from 160 degrees. The SO_2 concentration for the hour averaged 1.79 ppm at the Agriculture Building. A theoretical diffusion calculation was made to determine if such an extreme hourly value could be accounted for. To accomodate the downwash aspect of the problem, the heating plant was assumed to be a volume source. The theoretical calculations yielded an hourly average concentration of 1.60 ppm, which is in quite good agreement with the value actually observed.

During the May sampling period at the Agriculture Building, winds from 150 to 230 degrees were observed 140 hours during which SO_2 data were simultaneously available. From September through June, the period of the year that the Central Heating plant operated, the frequency, based on 10 years of data, that Washington National Airport experiences 150- to 230-degree winds with speeds equal to or greater than 8 mph is 19 percent. Data in Table 54 indicate that when such winds occurred during the sampling period, concentrations of SO_2 equalled or exceeded 0.10 ppm 68 percent of the time and equalled or exceeded 0.25 ppm 42 percent of the time. It is therefore conservatively estimated that during a September to June heating season, the Central Heating Plant will cause 0.10 ppm or greater concentrations of SO_2 to occur at the Agriculture Building at least 13 percent of the time and 0.25 ppm or greater concentrations at least 8 percent of the time. Furthermore, the daily variation in wind speed is such that the frequency of wind speeds that equal or exceed 8 mph is greatest from 1000 to 1600 EST. This period occurs during daytime working hours when the nearby office buildings are normally fully occupied.

Table 54. FREQUENCY OF OCCURRENCE OF SO_2 CONCENTRATIONS AT AGRICULTURE BUILDING AS A FUNCTION OF WIND SPEED, FOR WIND DIRECTIONS 150° TO 230° INCLUSIVE, (MAY 4-18, 1967)

SO_2 ppm	Wind speed	
	<8 mph	≥ 8 mph
≥ 0.10	25%	68%
≥ 0.25	6%	42%

Many tourist attractions, including the Washington Monument, the Smithsonian Institution, and the grounds of the U.S. Capitol are within a few blocks to a mile of the Central Heating Plant. These points are considerably more distant and in somewhat different directions from the plant than is the Agriculture Building. It was estimated that hourly SO_2 concentrations as high as 0.75 ppm could be experienced near the Smithsonian Institution; 0.6 ppm on the Washington Monument grounds; and 0.4 ppm on the grounds of the U.S. Capitol. These locations are downwind of the heating plant 3, 1, and 1 percent of the time, respectively.

IMPACT OF BENNING RD. POWER PLANT IN PRINCE GEORGES COUNTY HOSPITAL

For 2 months during the study period concurrent data were available for SO_2 sampled at Prince Georges County Hospital, Cheverly, Maryland, and for vertical temperature difference and wind measured at Silver Hill, Maryland. These two stations are sufficiently close to compare data directly and,thus, to determine rather precisely how atmospheric conditions affected the distribution of SO_2 from a point source.

On three occasions when average hourly concentrations of 0.10 to 0.20 ppm SO_2 were measured between 0800 and 1000 EST at Cheverly, the following meteorological conditions were observed.

1. The wind was southwest 5 to 10 mph.
2. From midnight until 0600 EST an inversion extended from the surface to 300 feet or above.
3. Between 0600 and 0800 EST the inversion between 100 and 300 feet was eliminated; the inversion below 100 feet persisted.
4. Between 0800 and 1000 EST the surface inversion was dissipated and the entire layer below 300 feet became unstable. These meteorological data indicate the possibility of a "fumigation" if a SO_2-bearing plume were in this vicinity.

The fumigation would not be in the classical sense where a fanning plume is quickly mixed downward as the layer becomes unstable. In the cases observed, the plume would have already been in a neutral atmosphere and probably coning The inversion next to the surface (between 0600 and 0800 EST) would inhibit the plume from reaching ground level. When this inversion dissipated and the entire layer below 300 feet became unstable, the coning plume would mix to the surface, resulting in a modified fumigation. In this case, the observed concentrations would be expected to be less and persist for a shorter period than in the classical case.

The Benning Road Power Plant is in the District of Columbia, 5 kilometers to the southwest of the Prince George's Hospital. On the three occasions discussed, its plume would be streaming toward the hospital. For the meteorological conditions specified it was found by use of Holland's plume-rise equation that the height of the plume would be about 400 feet. The modified fumigation was calculated to cause a short-period, ground level concentration on the plume's centerline as high as 0.3 ppm. This value is in good agreement with the hourly concentrations of 0.1 to 0.2 ppm observed at the Cheverly station under these conditions.

It is concluded that under appropriate meteorological conditions the Benning Road Power Plant can cause SO_2 concentrations typical in magnitude and duration to those observed at Prince George's Hospital in Maryland. Further, it is concluded that under these circumstances interstate transport of significant amounts of SO_2 occurs.

IMPACT OF OXIDANTS

An analysis of hourly concentrations of oxidants at four stations provides an indication that interstate transport of air pollutants takes place in the Washington Metropolitan Area. Assuming that the predominant source-areas of pollutants which interact to produce elevated oxidant levels is near downtown Washington and that pollutants must undergo photochemical reaction to create elevated oxidant levels, the following analysis was performed. All days were selected when hourly oxidant levels reached 0.08 ppm at Cheverly, when winds at the 300-foot level of the Silver Hill tower were south clockwise through northwest, and when the percent of possible sunshine exceeded 50 percent. The average hourly concentration of oxidants was computed and plotted against time of day. (Figure 52) The figure shows that the southernmost station sensed very low oxidant concentrations. The other three stations had marked peaks. Cheverly, which was in all cases downwind from the center of the metropolitan area, reached maximum average concentrations 3 hours later than the CAMP station located in downtown Washington.

The average maximum concentration at Cheverly was 60 percent higher than that at CAMP as expected since only days that Cheverly experienced high values were selected. However, the time of occurrence of the maximum concentration was 2 hours later at Cheverly than at CAMP. The constituents that produce the oxidants require time to undergo a photochemical reaction. Since only days with District to Maryland airflow were selected, the reaction could take place as the "raw materials" were moving from the District to nearby Maryland.

It is recognized that the Cheverly site is near the heavily traveled Baltimore-Washington Parkway. Effluents from the Parkway traffic however would have had a very brief exposure to sunlight before they reached the Cheverly sensor; and by the time the afternoon traffic peak was reached, oxidant concentrations had fallen by 20 percent from their peak values. It would appear that the nearby traffic was not the originating source of the contamination.

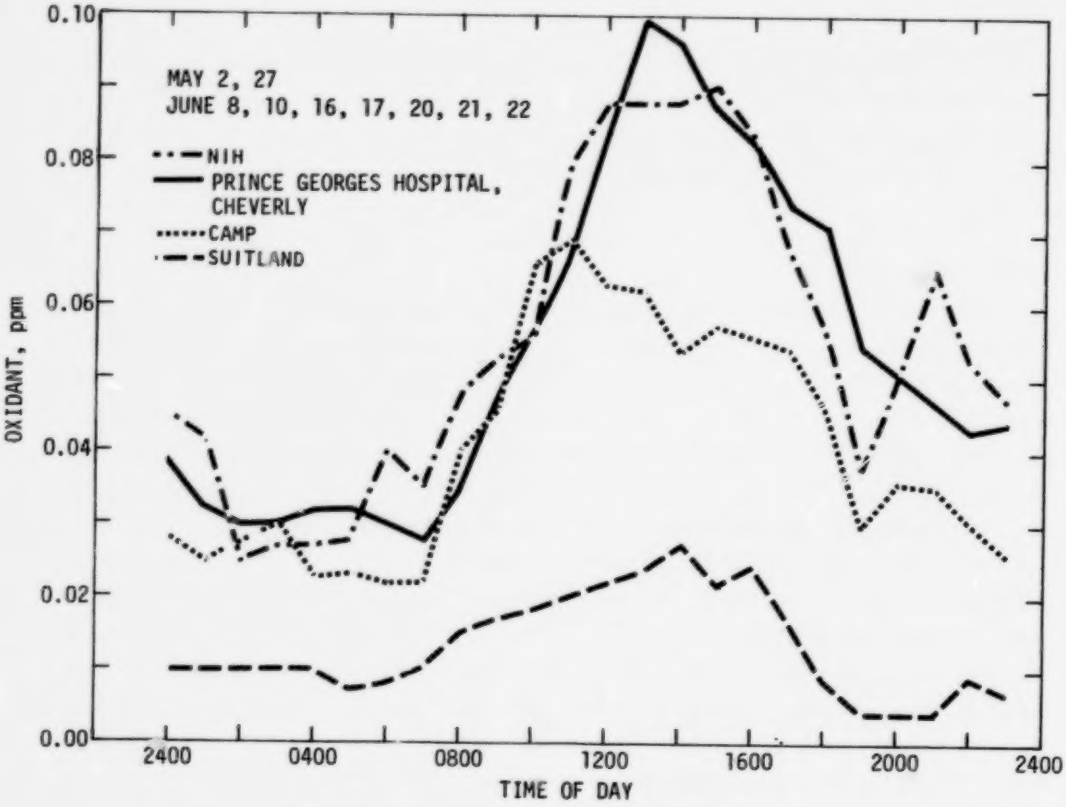


Figure 52. Mean hourly oxidant concentrations for days specified.

VII. POLLUTANT EFFECTS AND CRITERIA

PARTICULATE POLLUTION

Effects

Although particulate air pollution is known to interfere with visibility, to cause soiling and to promote the deterioration of materials and is generally a significant nuisance factor, its adverse effects on community health, though somewhat more subtle, are nevertheless significant.

There are four areas of concern relative to the health effects of particulate matter pollution on humans:

1. The ability of the respiratory tract to separate particulates from inhaled air and retain them in the lungs.
2. The presence in some particulate material of metallic or mineral substances having toxic or other physiological effects.
3. The presence in some particulate material of polycyclic hydrocarbons having demonstrated carcinogenic properties.
4. The demonstrated ability of fine particles to enhance the harmful physiological activity of gaseous pollutants or to convert these to other more harmful materials when both are simultaneously present in inhaled air. Of particular concern in this area is the ability of certain airborne mineral substances to increase the rate at which atmospheric sulfur dioxide is oxidized to the much more physiologically active sulfur trioxide. Also, while sulfur dioxide gas appears to be relatively harmless in the upper respiratory tract, it is seldom inhaled alone. It can be adsorbed on particulate matter and transported into the sensitive portions of the lungs.

The size of airborne particles has an important bearing on whether and to what extent they reach the lungs. Most coarse material - particles about 5 microns or more in diameter - lodges in the upper respiratory passages. Smaller particles are more likely to penetrate into the lungs; in the range of about 1 to 5 microns the rate of lung deposition increases with decreasing particle size. Particles smaller than 2 to 3 microns usually reach the deeper structures of the lungs, where there is no protective mucous blanket. A major portion of the suspended particulate matter measured in this investigation falls into this latter category.

There is little doubt that particulate aerosols at the concentrations found in the ambient air of this area are injurious to sensitive persons. Although the particulate levels measured during this activity are not now known to be high enough to affect the normal healthy members of the community, they are high enough to cause a aggravation of illness among persons with pre-existing respiratory ailments. These people represent a significant portion of the community since it has been conservatively estimated that in excess of 10 percent of our adult population today suffers from some stage of pulmonary emphysema, bronchitis, or other respiratory abnormality.

A recent epidemiological study of asthma in New Orleans, where measured levels of suspended particulate loadings were similar to levels found in this area, established a positive relation between hospital admissions of asthma patients and the amount of "poor combustion" silica-associated particles sampled. These "poor combustion" particles were traced to the smoke plumes resulting from spontaneous dump fires.

The primary effect of inert airborne solids on community welfare is soiling. Although these particles may directly cause only minimal deterioration, the cleaning of soiled objects is costly and the cleaning process shortens the useful life of many items upon which grime is deposited. Recently a professional economist concluded that it costs everyone in an adjacent metropolitan area approximately $200 annually to combat the multiple effects that all contaminants impose on their person and property. Certainly, a major portion of this cost is due to soiling from particulates in the air.

Criteria

Table 55 presents a summary of the current air quality goals adopted or proposed for particulates in many portions of the United States.

Table 55. AIR QUALITY STANDARDS, CRITERIA, AND OBJECTIVES - PARTICULATES

Suspended particulate - high-volume sampler

State of New York
Regional Objective "C" Sub-Region 2
65 $\mu g/m^3$ (24-hr avg) 50% of values less than
100 $\mu g/m^3$ (24-hr avg) 84% of values less than
Regional Objective "C" Sub-Region 3
80 $\mu g/m^3$ (24-hr avg) 50% of values less than
120 $\mu g/m^3$ (24-hr avg) 84% of values less than

State of Missouri
St. Louis Metropolitan Area
75 $\mu g/m^3$ annual geometric mean
200 $\mu g/m^3$ not to be exceeded 1% of days per year

Table 55. (continued)

- State of Colorado
    - 120 μg/m^3 average for any 3-month period
- State of Oregon
    - Residential and commercial area
        - 150 μg/m^3 plus normal background value
    - Heavy industrial area
        - 250 μg/m^3 plus normal background value
- State of Pennsylvania
    - Air basin average
        - 100 μg/m^3
    - Single-point measurement
        - 150 μg/m^3 30-day average
        - 500 μg/m^3 24-hr average
- State of West Virginia
    - Kanawha Valley
        - 100 μg/m^3 annual geometric mean
        - 250 μg/m^3 not to be exceeded 1% of days per year
- State of Texas
    - Type A land use, residential and recreational
        - 125 μg/m^3 not to be exceeded 90% of time based on the average of 10, 24-hr samples taken with in a 20-day period
    - Type B land use, commercial and business
        - 150 μg/m^3 same as above
    - Type C land use, industrial
        - 175 μg/m^3 same as above
    - Type D land use
        - 200 μg/m^3 same as above
- State of Montana
    - 75 μg/m^3 annual geometric mean
    - 200 μg/m^3 not to be exceeded more than 1% of days per year

Suspended particulate - soiling - AISI sampler

- State of New Jersey
    - Adjectival rating scale (not a standard)

        0 - 0.9 Coh per 1000 lineal feet - light
        1.0 - 1.9 Cohs per 1000 lineal feet - moderate
        2.0 - 2.9 Cohs per 1000 lineal feet - heavy
        3.0 - 3.9 Cohs per 1000 lineal feet - very heavy
        4.0 - plus Cohs per 1000 lineal feet - extremely heavy

Table 55. (continued)

State of Colorado

0.5 Coh per 1000 lineal feet - average any 3-mo period

State of Missouri

St. Louis Metropolitan Area

0.4 Coh per 1000 lineal feet - annual geometric mean

Settleable particulate - dustfall

State of New York

Regional Objectives "C" Sub-Region 2

0.60 $mg/cm^2/mo$	(17.1 $tons/mi^2/mo$)-	50% of values less than
0.80 $mg/cm^2/mo$	(22.8 $tons/mi^2/mo$)-	84% of values less than
0.90 $mg/cm^2/mo$	(25.7 $tons/mi^2/mo$)-	50% of values less than
1.20 $mg/cm^2/mo$	(34.3 $tons/mi^2/mo$)-	84% of values less than

State of Missouri

St. Louis Metropolitan Area

10 $tons/mi^2/mo$	3-mo average above background (5 $tons/mi^2/mo$) all areas except zoned heavy industrial
25 $tons/mi^2/mo$	3-mo average above background (5 $tons/mi^2/mo$) heavy industrial areas

State of Oregon

15 $tons/mi^2/mo$	Residential or commercial concentration shall not exceed stated values plus normal background
30 $tons/mi^2/mo$	Heavy industrial areas, concentration shall not exceed stated value plus normal background.

State of Pennsylvania

Air basin average

1.0 mg/cm^2 (28.6 $tons/mi^2$) - 30-day period

Single-point measurement

1.5 mg/cm^2 (42.8 $tons/mi^2$) - 30-day period

State of Montana

15 $tons/mi^2/mo$	3-mo average, residential areas
30 $tons/mi^2/mo$	3-mo average, heavy industrial areas

SULFUR OXIDES POLLUTION

Effects

There is evidence that the sulfur oxides family of pollutants, specifically, sulfur dioxide, sulfur trioxide, their acids, and their acid salts, aggravate existing human respiratory disease as well as contribute to its development. As previously indicated, the effects on human health becomes considerably more pronounced when these contaminants are found in combination with suspended particulate matter.

The contribution of sulfur oxides pollution during disaster episodes, i.e., when levels of these contaminants were excessively high (as were levels of other pollutants) has been specifically documented. But, low-level, long-term exposure, as well as short-term fumigations affect not only the health but the social and economic welfare of the urban community. The tabulation in Table 56 summarizes some of these multiple effects, which have been determined from a significant body of scientific evidence.

Table 56. SUMMARY OF MULTIPLE EFFECTS
FROM EXPOSURE TO SULFUR DIOXIDE

Concentration and time	Effects
0.02 to 0.03 ppm for 1 year	Increased respiratory disease death rates in humans
	Corrosion of metals becomes significant
	Injury to perennial vegetation
0.1 to 0.3 ppm for 2 to 4 days	Increases in hospital admissions and mortality due to cardiorespiratory disease
	Increases in prevalence of rhinitis, sore throat, cough, and eye irritation
	Mild acute injury to sensitive vegetation
0.3 to 1.0 ppm for 1 hour or less	Threshold for increased respiration and pulse rates of humans
	Taste and odor threshold for humans

Criteria

Table 57 presents a summary of current air quality goals adopted or proposed for sulfur oxides in many portions of the United States.

Table 57. AIR QUALITY STANDARDS, CRITERIA, AND OBJECTIVES - SULFUR OXIDES

Area	Standard criteria not to exceed stated concentration
Sulfur Dioxide	
California	0.30 ppm average for 8 hr 1.0 ppm average of 1 hr
Colorado	0.10 ppm 1% of time any 3-mo, 24-hr average 0.50 ppm 1% of time any 3-mo, 1-hr average
Dade County, Fla.	0.10 ppm average for 8 hr
New York State	0.10 ppm 1% of time
(Vary according to regions)	to 0.15 ppm 2% of time, 24-hr average
St. Louis (Metropolitan)	0.02 ppm, annual average 0.10 ppm 1% of days in any 3 consecutive mo, 24-hr average 0.20 ppm once in any 4 consecutive days, 1-hr average
Pennsylvania	0.5 ppm 1-hr average 0.25 ppm 24-hr average 0.05 ppm 30-day average
Public Health Service	0.10 ppm once in 100 consecutive days, 24-hr average 0.25 once in 4 consecutive days, 1-hr average
Sulfuric acid mist	
New York State (all regions)	10 $\mu g/m^3$, 24-hr average
State of Missouri	4 $\mu g/m^3$, annual average 12 $\mu g/m^3$, 1% of time 30 $\mu g/m^3$, 1% of time, hourly average
Sulfate (suspended particulates)	
State of Missouri (St. Louis Metropolitan) and State of Montana	4 $\mu g/m^3$ annual average 12 $\mu g/m^3$, 1% of time

PHOTOCHEMICAL POLLUTION

Effects

Atmospheric emissions of gases, mainly nitrogen oxide and unsaturated hydrocarbons, when energized by sunlight (photochemical reaction), produce a major class of pollutants called oxidants. The principal identifiable oxidants in photochemical smog are ozone, peroxacyl nitrates (PAN), and nitrogen dioxide.

Certain associative or group effects of oxidants have been identified. The one most commonly experienced is eye irritation, which is generally experienced in almost every urban area in the country when levels of total oxidants exceed 0.1 ppm for several hours. A sharp, pungent odor often characterizes the phenomena at this or higher levels. Pulmonary studies have shown that chronic respiratory disease patients suffer considerable distress from airway resistance produced at the 0.1 ppm exposure level. In both long-and short-term studies on animals, photochemical smog at levels often found in the ambient air produced a variety of effects, ranging from increased susceptibility to many respiratory ailments to increased incident of lung tumors in older specimens.

Ozone is known to severly irritate mucous membranes and will cause such reaction in the nose and throat after exposure in the range of 0.05 to 0.10 ppm for 15 to 30 minutes. At higher levels, 0.30 to 1.0 ppm, and for slightly longer exposures ozone produces coughing, chapping, severe fatigue, and a decrease in visual acuity. At levels commonly found in urban atmospheres it has been shown to deteriorate rubber, fade some dyed materials, and cause moderate to severe damage in sensitive vegetation and crops.

The most extensive information gathered on the extent of biological harm resulting from nitrogen dioxide indicates that animals exposed to low levels (0.5 to 3.5 ppm) exhibited increased susceptibility to infection and subsequent increased mortality.

Criteria

Table 58 presents a summary of the current air quality goals adopted or proposed for oxidants and nitrogen dioxide in several areas in the United States.

Table 58. AIR QUALITY STANDARDS, CRITERIA AND OBJECTIVES - OXIDANTS

Areas	Standard or criteria, average concentration, ppm
Total Oxidants	
California	0.15 for 1 hr (adverse level)
Colorado	0.10 for 1 hr for greater than 1% of time in any 3-mo period.
New York	0.15 for 1 hr
	0.10 for 4 hr for certain regions
St. Louis (Metropolitan)	0.15 for 1 hr
Nitrogen Dioxide	
California	0.25 for 1 hr
Colorado	For total oxides of nitrogen 0.1 for 1 hr for greater than 1% of the time in any 3 mo
Pennsylvania	0.5 for 30 days

CARBON MONOXIDE

Effects

Since carbon monoxide is one of the most common gaseous toxicants, and has the ability to lower the oxygen-carrying ability of the blood, its effects have been well documented. At or near concentrations of 100 ppm, many people exposed for 1 to 2 hours experience headaches and a decrease in physical and mental abilities. For persons already suffering a disease involving reduced oxygen transport or ventilatory capacity, i.e., anemia, heart impairment, or asthma, the extra burden imposed on the system by ambient levels of carbon monoxide (50 to 100 ppm) might cause injury to vital organs. Such individuals may tolerate extended exposures to a carbon monoxide concentration of 5 ppm more easily than to higher levels; a concentration of 5 ppm would reduce oxygen transport ability about 1 percent. Even healthy persons who have been smoking or drinking, who are undergoing treatment with certain drugs, or who are at a high altitude, are more susceptible to carbon monoxide and may experience effects similar to fatique or drunkeness upon exposure.

Extensive work with animals exposed to levels commonly found in traffic exhibited a significant reduction in altertness and ability to integrate various stimuli.

Criteria

Table 59 presents a summary of the current air quality goals adopted or proposed for carbon monoxide in several areas of the United States.

Table 59. AIR QUALITY STANDARDS, CRITERIA AND OBJECTIVES - CARBON MONOXIDE

Area	Standards or criteria, average concentration, ppm
California	30 for 8 hr (serious level) 120 for 1 hr (serious level)
New York	30 ppm for 8 hr 15 for 8 hr, for more than 15% of the time
St. Louis (Metropolitan)	30 for 8 hr 120 for 1 hr
Pennsylvania	25 for 24 hr

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APPENDICES

Appendix A. Description of Project Design

Appendix B. Aerometry Operation and Techniques

Appendix C. Emissions Inventory Procedure

Appendix D. Tables and Figures

Appendix A DESCRIPTION OF PROJECT DESIGN

AIR QUALITY NETWORK

Scope

The objectives of the air quality investigation were:

1. To assess the sources, characteristics, concentrations, and interstate movement of air pollution that may affect health and welfare in the interstate Washington, D. C., metropolitan area.

2. To promote the development of an effective program for abatement and prevention of air pollution in the interstate Washington, D. C., metropolitan area.

Criteria for Network Design

Three factors were basic in determining the criteria for the network design:

1. Conference date. A general date for the conference; namely, late Fall 1967, permitted the network to be designed for all but fall weather conditions. There would be little opportunity to process and analyze data collected after July 1967.

2. Availability of samplers. The first pieces of Public Health Service air quality sampling equipment would not be available before January 15, 1967, and the last of the equipment would be ready in March 1967.

3. Established sampling sites. The Metropolitan Washington Council of Governments had a network of more than 30 static sampler sites. All of these sites were equipped with dustfall recepticals, and many had sulfation candles and rubber-cracking stands. A Continuous Air Monitoring Program (CAMP) station was already in operation in the central city.

From these factors, the following important and controlling considerations evolved:

1. The design should be consistent with existing sampling sites, including those already operated by the Council of Governments.

2. A network should be designed to sense all types of emissions. Because of the length of the sampling period nearly all emissions would be encountered.

3. The basic network should be oriented with the most prevalent wind directions during the time of sampling. Such orientation would increase the efficiency with which the sampling equipment could be used. Samplers would be placed to represent areas of habitation

or occupation; some should be downwind of the major source areas a high percentage of the time; others should be placed to observe the lateral spread of contaminants; and still others should be placed to note background contamination levels.

Meteorological Factors

Meteorological factors, specifically wind directions, were used in the orientation of the network.

Data From Other Agencies

It was agreed early in the study that most of the data obtained from regional and local participating agencies would be handled through the Metropolitan Washington Council of Governments (COG). COG had already established a system for handling samples and data collected by local health departments participating in the COG air quality networks. In a few cases, however, the local agency was contacted directly for data.

Arrangements were also made to receive tabulations of the data collected by the Washington CAMP station during the course of the abatement study. It was also agreed that all data yielded by the investigation would be tabulated by the Public Health Service and distributed to all participating agencies not less than 30 days prior to the Conference.

Public Health Service Sites

After due consideration to the location of existing sampling sites, the Field Operations Activity of the Abatement Program had primary control in the selection of the other major sampling sites. Criteria for selection of the sites were as follows:

1. The site must be compatible with existing sampling stations (COG and CAMP).

2. The site must represent as large an area as possible. It should not be adjacent to a major pollution source, but it should be in a moderately to heavily populated or traveled area, unless the station is used as a background sampling site.

3. The site must be located so that nearly all obstructions are minimal. If obstructions are present, the distance between the site and the obstruction should be at least 2.5 times the difference in height between the sample intake manifold and the height of the nearest obstruction. If obstructions are unavoidable, the nearest obstruction should be to the east of the site.

4. The site should be reasonably convenient to commercial 215-to 230-volt, 100-ampere power.

5. The site should be located so that it is not obviously vulnerable to vandalism or so that precautions against vandalism can be taken.

6. The site should be reasonably convenient to the U.S.Naval Station to minimize travel time to and from the Station, the home office of maintenance personnel.

7. The site should be owned or controlled by persons or agencies sympathetic to the objectives of the project to avoid undue complications in negotiating for access to the site.

A number of potential sites satisfied the criteria. Because the CAMP station was located in the central city, it was not necessary to establish one there. One of the mobile stations was located on the National Institutes of Health (NIH) reservation in Bethesda, Maryland. This site was to be used primarily for background measurements. A second mobile station was located in Alexandria, Virginia, an area of expected pollution and near an interstate boundary. A third mobile station was located in Suitland, Maryland, near the District of Columbia line and downwind of much of the study area. Another major site in Hyattsville, Maryland was later moved to Cheverly, Maryland. A fifth site was located in the Seven Corners area of Fairfax County, Virginia. This station provided a degree of symmetry to the network. Other stations with only minor equipment were located at or near National Airport, the Kenilworth Dump, U.S. Naval Station, and 1500 Rhode Island Avenue, N.W.

Final Network

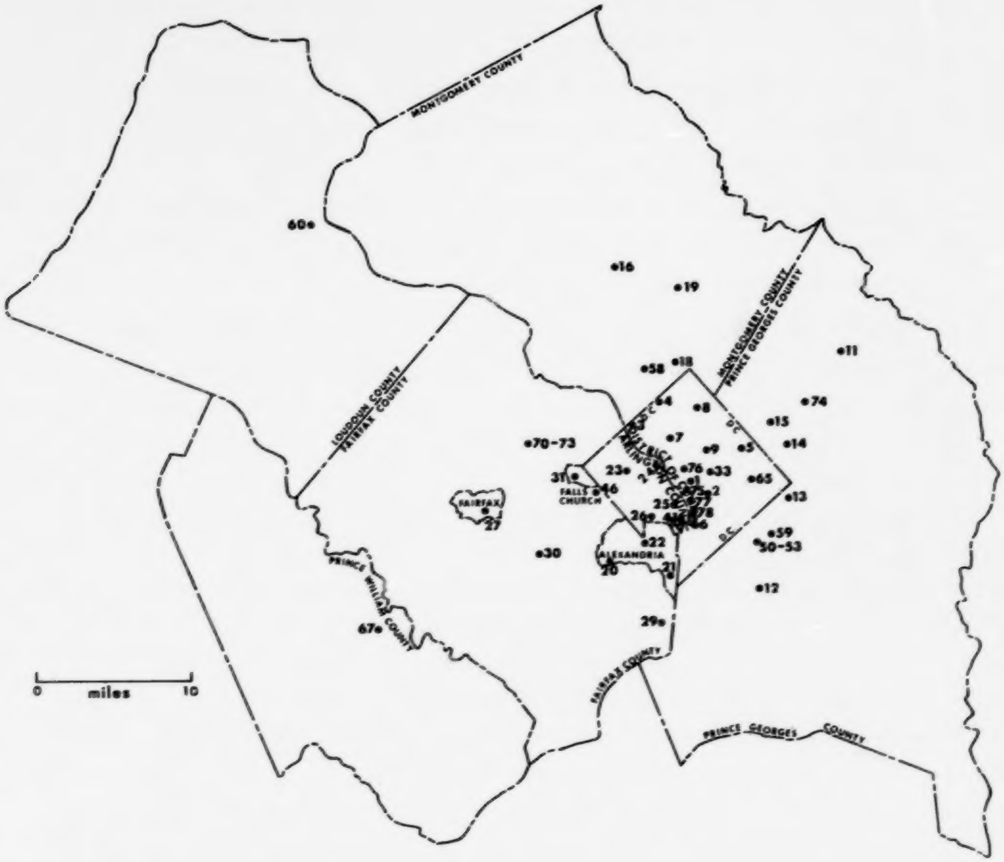
The location of all sites and the pollutants sampled are shown on Figure A-1. All the major sites sampled for SO_2 and OX's. The three mobile sites also sampled for CO, NO_2, and NO_x, and the NIH station sampled HC as well.

High-volume filter samplers for suspended particulate were installed at nine locations during the time of the study. A total of 31 static stations were located in the study area. All of these contained a dustfall receptical and many also had sulfation candles and rubber-cracking exposure shelters.

A listing of all stations and their sampling equipment appears in Section B of the Appendix.

A description of the characteristics of each major sampling site and meteorological data follows.

Station 14 - Cheverly, Md. This site was located on the roof of the Prince Georges County Health Department Building. The building is on a sloping hill above and east of the Baltimore-Washington Parkway. The exposure is excellent to the southwest and west to northeast. The crest of the hill to the east to south about a quarter mile distant rises to about rooftop level.


MONTGOMERY COUNTY
LOUDOUN COUNTY
FAIRFAX COUNTY
MONTGOMERY COUNTY
PRINCE GEORGES COUNTY
PRINCE WILLIAM COUNTY
FAIRFAX COUNTY
PRINCE GEORGES COUNTY
DISTRICT
ARLINGTON
D.C.
D.C.
FAIRFAX
FALLS CHURCH
ALEXANDRIA
60
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58
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74
64
8
15
14
7
9
5
70-73
23
76
33
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31
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1
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78
26
22
59
50-53
30
20
21
12
27
67
29
0
miles
10

Figure A-1. Washington area air quality monitoring network.

Exposure is good from these directions, and air quality data collected at this site are considered representative of the northeast portion of the study area.

Station 15 - Hyattsville, Md. This site was located at 4318 Hamilton Avenue, near the intersection of Rhode Island and Baltimore Avenues. It was on the roof of a building, about 35 feet above street level in a built-up, mixed residential-commercial area. Buildings are low to the north and west. To the south and east, higher buildings obstruct airflow. The site was moved to Cheverly when a local source was found to seriously bias air quality data.

Station 21 - Alexandria, Va. This site was at street level in a department store parking lot. Three-and four-story buildings are across the street to the east and northeast, 300 feet to the west and south. The site was fairly adequate for air quality sampling. It was deemed necessary to move the wind

LEGEND FOR FIGURE A-1

Sta. No.	Station Name	Sulfur Dioxide	Total Oxidant	Nitrogen Dioxide	Nitrogen Oxides	Carbon Monoxide	Hydro-carbon	Suspended Particulate	Respirable Dust	Soiling	Meteorological Equipment	Dustfall	Sulfation Candle	Rubber Cracking	Effects Package	Vegetation Chamber	Service Agency
1	Treasury Building											*	*				D.C.
2	Capitol Hill											*	*				D.C.
3	Delecarla Reservoir											*					D.C.
4	Chevy Chase											*					D.C.
5	St. Frances de Sales School											*	*				D.C.
7	Footer Building											*	*				D.C.
8	Basil Building											*	*	*			D.C.
9	McMillan Reservoir											*					D.C.
11	Greenbelt High School											*	*				P.G.
12	R.B. Tanny High School											*					P.G.
13	Capital Heights											*	*				P.G.
14	P.G. Hospital Cheverly	*	*					*							*		P.H.S

LEGEND FOR FIGURE A-1 (Continued)

Sta. No.	Station Name	Sulfur Dioxide	Total Oxidant	Nitrogen Dioxide	Nitrogen Oxides	Carbon Monoxide	Hydro-carbon	Suspended Particulate	Respirable Dust	Soiling	Meteorological Equipment	Dustfall	Sulfation Candle	Rubber Cracking	Effects Package	Vegetation Chamber	Service Agency
15	Hyattsville	*	*					*				*	*	*			P.H.S
16	Rockville Health Dept.											*	*	*			M.
18	Rosemary Hill											*	*				M.
19	Glenmont											*					M.
20	Cameron Sta.											*	*				AL.
21	Alexandria	*	*	*	*	*		*	*	*	*				*	*	P.H.S
22	T.C. Williams High School											*					AL.
23	Mason Center											*		*			AR.
24	Drew											*	*				AR.
25	Fish Exchange Bldg.											*					AR.
26	Gas Light Bldg											*					AR.
27	Fairfax Lib.											*	*	*			F.

LEGEND FOR FIGURE A-1 (Continued)

Sta. No.	Station Name	Sulfur Dioxide	Total Oxidant	Nitrogen Dioxide	Nitrogen Oxides	Carbon Monoxide	Hydro-carbon	Suspended Particulate	Respirable Dust	Soiling	Meteorological Equipment	Dustfall	Sulfation Candle	Rubber Cracking	Effects Package	Vegetation Chamber	Service Agency
29	Westgate											*	*	*			F.
30	Belvedere School											*	*				F.
31	Falls Church Bank											*					F.
33	C.A.M.P.	*	*	*	*	*	*	*	*	*	*				*		D.O.
41	National Airport							*				*	*				P.H.S
46	7-Corners	*	*					*				*	*	*			P.H.S
50-53	Silver Hill Tower										*						ESSA
58	N.I.H. Bethesda	*	*	*	*	*	*	*			*	*	*	*		*	P.H.S
59	Suitland Census Bureau	*	*			*		*		*	*	*	*	*			P.H.S
60	Loudoun Co. Health Dept.														*		L.
65	Kenilworth Dump							*									P.H.S
66	U.S. Naval Sta.	*										*	*	*			P.H.S
67	Prince William Co. Manassas, Va.											*	*	*			P.W.

LEGEND FOR FIGURE A-1 (continued)

Sta. No.	Station Name	Sulfur Dioxide	Total Oxidant	Nitrogen Dioxide	Nitrogen Oxides	Carbon Monoxide	Hydro-carbon	Suspended Particulate	Respirable Dust	Soiling	Meteorological Equipment	Dustfall	Sulfation Candle	Rubber Cracking	Effects Package	Vegetation Chamber	Service Agency
70-73	Tysons Corner Tower										*						ESSA
74	Calvert Mansion (Police Sta.)															*	P.H.S
75	Geo. Washington Monument		*													*	P.H.S
76	Paint & Varnish									*							P.H.S
77	S. Agriculture Building	*															P.H.S
78	Park Police (Park Service)														*		D.C.

D.C. - District of Columbia
P.H.S. - Public Health Service
AL. - Alexandria City
F. - Fairfax County
L. - Loudoun County

P.G. - Prince Georges County
M. - Montgomery County
AR. - Arlington County
CAMP - Continuous Air Monitoring Program
P.W. - Prince William County
ESSA - Environmental Science Services Administration

sensor to the roof of the Red Cross Building about 200 feet to the northeast of the air sampling trailer. Exposure was excellent for a rooftop site.

Station 33 - The Continuous Air Monitoring Program site at 1st and L Sts, N.W., in Washington, D. C., has been in operation for 5 years. The site is in an area being demolished for urban renewal. The nearest buildings are two and occasionally three stories in height and are from 150 to 300 feet distant. The wind sensor was on a 30-foot mast, and exposure was excellent for an in-city site. Particulate data may be occasionally biased, depending on the extent of the nearby demolition and construction activity.

Station 41 - National Airport. The wind sensors are exposed on the airfield. No local influences can be discerned.

Station 46 - Willston School, Seven Corners, Va. The sensors were on a roof 35 feet above the ground. The only obstruction of any type to free circulation of airflow was an apartment complex.

Station 50 - Silver Hill Tower, Md. This site is on a grassy hilltop about 1 mile west of the Suitland station (59). A square tower operated by the Department of Defense was instrumented with wind sensors at the 100, 200, and 300-foot levels and with temperature sensors at the surface, 100-, 200-, and 300-foot levels by the U.S. Weather Bureau, ESSA. Exposure is excellent.

Station 58 - National Institutes of Health, Bethesda, Maryland. This site was in a low area about 50 feet south of Cedar Lane, 400 feet west of Wisconsin Avenue, and 100 feet north of the NIH north parking lot. The terrain sloped sharply upward to the north and less sharply to the south. Wind data are representative of the very immediate area only. Air drainage is to be expected. Correlation of air quality and wind data should not be expected to provide reliable results.

Station 59 - Bureau of Census Parking Lot, Suitland, Md. This site is located on the periphery of the parking lot next to Silver Hill Road. Exposure is excellent. Nearest buildings are to the east across Silver Hill Road and are only one story. The Bureau of Census building is 300 to 500 feet to the west.

Station 66 - Naval Station, Anacostia, was the field laboratory of the Field Operations Activity, Abatement Program, National Center for Air Pollution Control, for the Washington Metropolitan Area Abatement Activity. The probe for the air sampling equipment extended from the northwest corner of the laboratory building about 10 feet above the ground. A hangar was located 200 feet to the east; and a three-story building, 300 feet to the north. There were no nearby pollution sources. Data are expected to be reasonably representative of ambient pollution levels.

Station 70 - Tysons Corner, Tower, Va. The installation and exposure is essentially identical to Station 50.

Station 77 - South Agriculture Building, 12th and C Streets, S.W. The sampling probe extended at essentially ground-floor window level into an inne court. Data acquired are not representative of surrounding areas, but indicate the effects of aerodynamic downwash of effluents from the Central Heating Plant a half block to the south.

PROJECT DESIGN OF EMISSIONS INVENTORY

Applications

The objective of this inventory is to locate and quantify emissions from industrial, governmental, commercial, and residential sources for the following applications:

1. To provide evidence of the existence of source emissions within the study area and to define the location, magnitude, frequency, duration, an relative contribution of these emissions.
2. To demonstrate by use of mathematical diffusion models the impact of air pollutants on receptor areas under the variety of meteorological conditions prevalent during the changing climatic conditions of the year.
3. To provide, by correlating the diffusion estimates with actual data from the air quality monitoring network, evidence whether interstate transport of air pollutants can and does occur, and whether it is of sufficient intensity and duration to endanger the health and welfare of the populati
4. To provide background data needed to evaluate the effectiveness of future control programs.

Technique

The technique utilized for this emissions inventory consists of the following general steps.

1. Division of the survey area into emission zones, based on similarities in land use, population density, fuel-use patterns, vehicular traffic patterns, or other definable homogeneities.
2. Accumulation of data on emission sources that are generally found to be broadly distributed within each zone. Included here are data for residential, institutional, commercial, and industrial space and water heating; on-site refuse incineration; and mobile sources.

3. Accumulation of data on major point sources located at specific sites within each emission zone. Included here are data for major fuel users, large refuse disposal, and industrial pollution sources.
4. Estimation of emissions of sulfur oxides, nitrogen oxides, carbon monoxide, particulate, and hydrocarbons based on fuel composition and quantities, types of processes and equipment, and appropriate emission factors. Where control equipment is utilized, actual or average collection efficiencies corresponding to the type of equipment are employed.
5. Calculation of the zone emissions for a minimum, average, and maximum space-heating day to demonstrate the contribution of area space heating and cooling demands to the total pollution load.

For this survey, the study area was subdivided into 72 emission zones.

DATA PROCESSING AND ANALYSIS

General

Methods of data handling and evaluation were an integral part of the overall project planning. Establishment of data-handling techniques was particularly important in view of the number of agencies involved and the variety of data collected.

Because many thousands of data items would be processed during the project, use of a computer for storage and retrieval was mandatory. Card formats were designed or modified to permit utilization of current Abatement Program computer programs for storage of the project data. Data formats were discussed with each participating agency to ensure that their data would be compatible for processing through the system. In some instances, hand tabulations were necessary to transform the existing data into the required formats.

Processing of Data

It was necessary to process data from different groups - the Metropolitan Washington Council of Governments, Continuous Air Monitoring Program, local agencies, and the Abatement Program. The stations operated by the above agencies ranged in complexity from units capable of automatic sampling of up to eight air quality and meteorological data items to static stations monitoring only dustfall. Additionally, data relative to emissions and air pollution effects were also collected and processed. A brief discussion of the processing of each of the main groups of data is presented.

Air Quality Data - For purposes of this discussion, air quality data are all data obtained through the sampling network, with the exception of meteorological data, which are discussed separately.

The flow diagram, Figure A-2, depicts the major elements of the data process from the time the sample is analyzed and a value recorded until the data are tabulated by the computer and analyzed. All air quality data from the participating agencies flowed through the Project Officer's office at the U.S. Naval Station. This provided central control to ensure prompt receipt of all data as scheduled. Any manual tabulations or calculations were completed at this time, and the data were then forwarded to Cincinnati, Ohio, for key punching and computer storage. Computer tabulations were compiled for each pollutant by station and time. These tabulations will be supplied to the participating agencies.

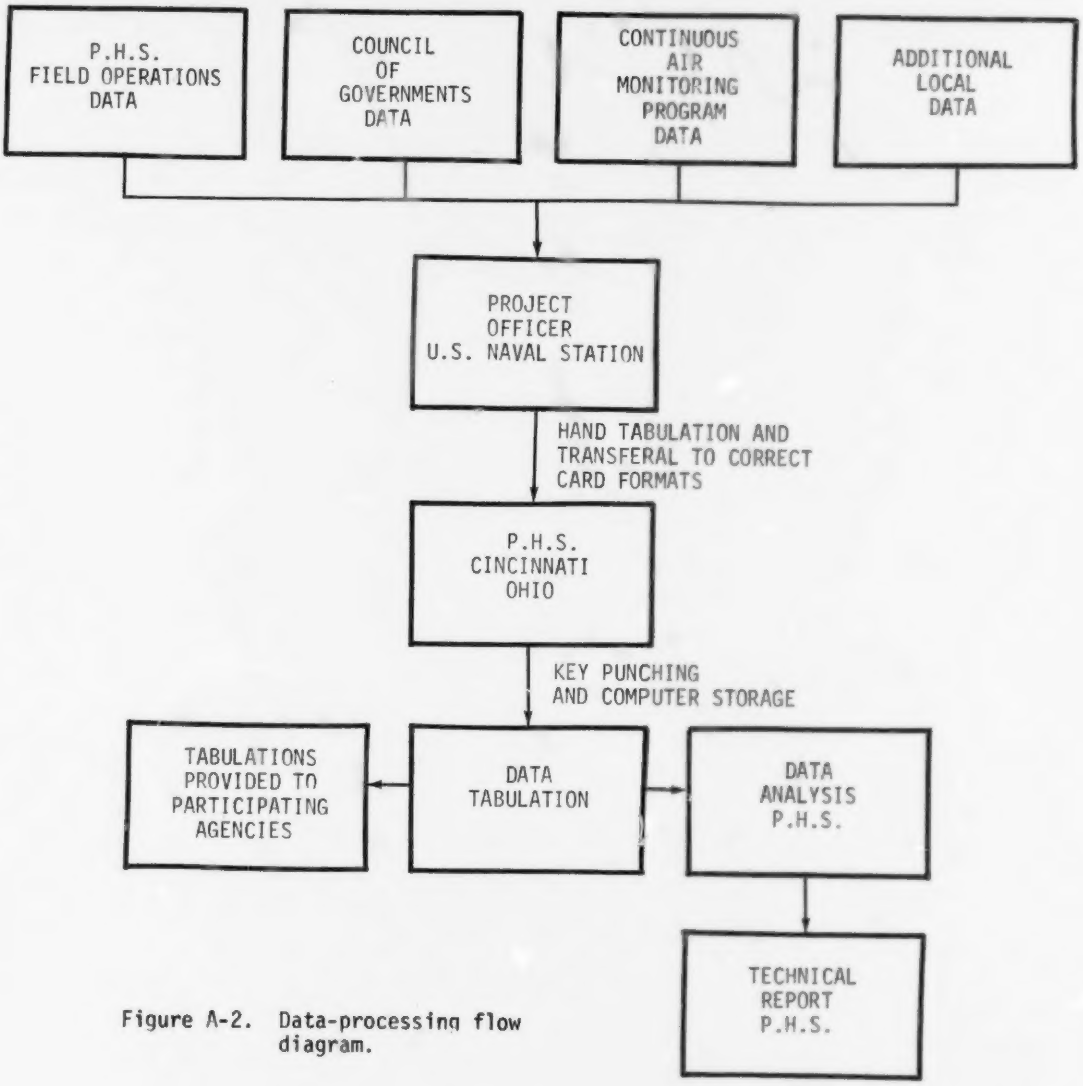
P.H.S. FIELD OPERATIONS DATA
COUNCIL OF GOVERNMENTS DATA
CONTINUOUS AIR MONITORING PROGRAM DATA
ADDITIONAL LOCAL DATA
PROJECT OFFICER U.S. NAVAL STATION
HAND TABULATION AND TRANSFERAL TO CORRECT CARD FORMATS
P.H.S. CINCINNATI OHIO
KEY PUNCHING AND COMPUTER STORAGE
TABULATIONS PROVIDED TO PARTICIPATING AGENCIES
DATA TABULATION
DATA ANALYSIS P.H.S.
TECHNICAL REPORT P.H.S.

Figure A-2. Data-processing flow diagram.

Meteorological Data - The meteorological data were processed in basically the same manner as the air quality data, the main differences being in the reduction procedures and the supplying agencies. Some agencies supplied the meteorological measurements directly, and they were then processed in the same manner as the air quality data. Other agencies, because of equipment differences, provided paper tapes that had to be read and evaluated manually prior to being key punched and stored in the computer. In addition to the data collected by the participating agencies, meteorological data were supplied by several stations operated by the U.S. Weather Bureau. These data were processed in the same way as the air quality data.

Emissions Inventory Data - Data were gathered for the emission inventory by means of questionnaires, plant visits, stack sampling and historical information. These data, because of their nature, were processed differently than the air quality or meteorological data. Detailed description of the emission inventory procedures are given in Appendix C.

Other Data - Additional data related to air pollution effects on the health or welfare of the inhabitants were gathered. These included data on vegetation studies, materials deterioration, and complaint records. These were manually tabulated rather than computerized.

Data Analysis

The tabulations present the data in formats that permit manual analysis; however, because of the large amount of data collected in this project, computer programs were written or existing programs modified to permit rapid data analysis. The more time-consuming and tedious tasks were given priority for computer programming. For purposes of description, data analysis techniques are divided into two classes; those involving a single pollutant or type of measurement, and those for which two or more pollutants or types of measurements are combined to provide more detailed information than can be obtained with one alone.

Single-Pollutant Techniques

Averages - Two measures for the average were computed: the arithmetic mean and the geometric mean. The arithmetic mean is the sum of the measurements divided by the number of measurements. The geometric mean is computed by finding the n^{th} root of the product of all the measurements. The geometric mean should be used to represent the data if the measurements are distributed log-normally, which is often the case with air pollution measurements. Computation of the average is important because it permits the use of a single number to represent a large amount of data.

Variability - As with the average, two measures of variability were computed: the standard deviation and the standard geometric deviation. These measures indicate the dispersion among the individual measurements. The standard deviation is used when the underlying distribution of the data is considered normal, whereas the standard geometric deviation is used if the measurements are distributed lognormally.

Frequency Distribution - Frequency distributions show what percent of the total measurements are less than a selected pollutant concentration or measurement level. A computer program performs the analysis and prints the resulting distribution. These distributions are valuable in that comparisons can be made with other data or criteria to determine relative degrees of pollution.

Iso-intensity Maps - Iso-intensity maps were constructed to determine the geographic distribution of specific pollutants over the Abatement Activity area. These maps were drawn by first determining the range of average values of the pollutant for all the stations and dividing this range into four approximately equal intervals. The average value for each station was then plotted and coded for the proper concentration interval. After all stations were plotted, areas of equal concentrations were determined and grouped into a single zone. The completed map then depicts zones of varying concentration levels throughout the area.

Combined-Pollutant Techniques

Wind Roses - Wind roses depict the percent of time winds from each of the 16 compass points occur. This information is necessary to explain transport of pollutants and to compare present conditions with past data. A computer program provides data for these wind roses.

Pollution Roses - Pollution roses combine meteorological data with pollution concentrations. A completed pollution rose indicates the percent of occurrences of each wind direction that are accompanied by a selected concentration level. Because pollution roses designate both direction and concentration, they can be used to indicate the locations of significant pollutant sources. These may be either point or area sources; however, the pollution rose probably more accurately depicts intensities of emissions from area sources than those from point sources, inasmuch as a small deviation in wind direction may cause emissions from any particular point source to miss a given receptor completely. The wind factor would not be so critical in the case of area emissions. Other factors affect the validity of indications obtained from pollution roses; among these are:

1. The capacity of the air to disperse pollutants; this varies with wind speed, which tends to differ with directions.
2. The height of emissions and distances to sources.
3. The frequency of occurrence of specific wind directions. During some seasons certain wind directions occur infrequently; others, with great frequency. These factors should be considered when interpreting pollution roses.

These analysis techniques provide means of presenting data so that logical interpretations of the results can be made. It is not possible, nor intended, to describe every aspect of data analysis in this report, but only to discuss briefly some of the more general techniques employed by the Public Health Service.

Appendix B. AEROMETRY OPERATION AND TECHNIQUES

INTRODUCTION

The air monitoring network designed by the Abatement Program, Public Health Service consists of automatic air monitoring and meteorological stations, combined with some semi-automatic continuous samplers and a nominal special sampling program. The design is integrated with existing air quality monitoring operations conducted by interstate and local agencies to produce air pollution data for statistical analysis. The air monitoring network will be described and discussed under appropriate headings.

AIR MONITORING STATIONS

The five Public Health Service stations consist of a main station (NIH), two satellite stations (Alexandria and Suitland), and two substations (Seven Corners and Hyattsville-Cheverly). The main station is equipped with five automatic analyzers for continuous measurement of SO_2, NO_2, or NO_x, CO, total oxidants, and total hydrocarbons. A complete wind measurement system and a digital data-logging system is also included.[B1] The Alexandria satellite stations contain analyzers for SO_2, OX, NO_2 or NO_x, and CO; instruments for wind measurements; and data-logging equipment. The Suitland Satellite station contained analyzers for SO_2, OX, and CO, instruments for wind measurement, and data-logging equipment. The two substations were equipped with SO_2 and OX air monitoring instruments. The remaining stations operated by the various agencies are fully or partially equipped to measure and log air pollution data. Table B-1 lists the air monitoring stations and types of sampling employed at each site.

LEAD PEROXIDE SULFATION CANDLES

A lead peroxide sulfation candle network was initiated to determine an index of the activity of SO_2 in the atmosphere and to provide a correlation with SO_2 automatic monitoring instruments.

A total of 21 sulfation candles were located in the study area. Their locations are given in Table B-1. An additional five candles were located at the effects station sites.

The method is based on exposing PbO_2 paste in ambient air and measuring the sulfation caused by gaseous SO_2. After exposure, the material is stripped from the candles with sodium carbonate, and the amount of sulfate is determined by a turbidimetric procedure. The sulfation rate is reported as milligrams of SO_3 per 100 square centimeters per day. Correlation studies have shown that multiplying the lead candle value by 0.04 gives an approximation of the average SO_2 concentration in ppm for the period of exposure. This factor when applied under applicable conditions permits gross estimates of SO_2 values [B2].

TABLE B-I. STATION SUMMARY

Station No.	Name and Address	Agency	Analyzer	Technique
1	Treasury Building 15th & Penn Avenue, N.W. Washington, D. C.	D.C.	Dustfall Sulfation Candle	PbO_2 Candle
2	Capitol Hill Library of Congress Washington, D. C.	D.C.	Dustfall Sulfation Candle	PbO_2 Candle
3	Delecarla Reservoir 5900 Mac Arthur Boulevard Washington, D. C.	D.C.	Dustfall	
4	Chevy Chase 5535 Connecticut Avenue, N.W. Washington, D. C.	D.C.	Dustfall	
5	St. Frances de Sales School 2019 Rhode Island Avenue, N.E. Washington, D. C.	D.C.	Dustfall Sulfation Candle	PbO_2 Candle
7	Poter Building 3333 Connecticut Avenue, N.W. Washington, D. C.	D.C.	Dustfall Sulfation Candle	PbO_2 Candle
8	Basil Building 509 Kennedy Street, N.W. Washington, D. C.	D.C.	Dustfall Sulfation Candle Rubber Cracking	PbO_2 Candle Weighted Strip
9	Mc Millan Reservoir 1st Street, N.W. Washington, D. C.	D.C.	Dustfall	

TABLE B-I (continued). STATION SUMMARY

Station No.	Name and Address	Agency	Analyzer	Technique
11	Greenbelt High School Greenbelt, Maryland	P.G.	Dustfall	
			Sulfation Candle	PbO_2 Candle
12	R. B. Tanny High School Brinkley Road near Allentown Road Prince Georges County, Maryland	P.G.	Dustfall	
13	Capitol Heights 62nd Street, S.E. Capitol Heights, Maryland	P.G.	Dustfall	
			Sulfation Candle	PbO_2 Candle
14	Prince Georges County Hospital Cheverly, Maryland	P.H.S.	SO_2	Colorimetric - West Gaeke (Sequential)
			OX	Colorimetric - Neutral KI (Technicon)
			Particulate	Hi-Vol
			Effects Package	
15	Hyattsville 4318 Hamilton Street Hyattsville, Maryland	P.H.S.	SO_2	Conductivity - H_2O_2 (Beckman)
			OX	Colorimetric - Neutral KI (Technicon)
			Particulate	Hi-Vol
			Dustfall	
			Sulfation Candle	PbO_2 Candle
			Rubber Cracking	Weighted Strip
16	Rockville Health Department 111 South Perry Street Rockville, Maryland	M.	Dustfall	
			Sulfation Candle	PbO_2 Candle
			Rubber Cracking	Weighted Strip
18	Rosemary Hill Sundale Drive Rosemary Hills, Maryland	M.	Dustfall	
			Sulfation Candle	PbO_2 Candle

TABLE B-I (continued). STATION SUMMARY

Station No.	Name and Address	Agency	Analyzer	Technique
19	Glenmont Georga Avenue Glenmont, Maryland	M.	Dustfall	
20	Cameron Station 4900 Duke Street Alexandria, Virginia	AL.	Dustfall	
			Sulfation Candle	PbO_2 Candle
21	Alexandria Pendleton and Saint Asaph Streets Alexandria, Virginia	P.H.S.	SO_2	Conductivity - H_2O_2 (Beckman)
			OX	Coulometric - KI (Mast)
			NO_2	Colorimetric - Saltzman (Beckman)
			NO_x	Colorimetric - Saltzman (Beckman)
			CO	Infrared (Beckman)
			Particulate	Hi-Vol
			Respirable Dust	Hi-Vol (cyclone pre-filter)
			Soiling Index	Smoke Shade
				AISI Tape Sampler
			Wind Speed	
			Wind Direction	
			Wind Sigma	
			Effects Package	
			Vegetation Chamber	
22	T. C. Williams High School King Street at Braddock Road Alexandria, Virginia	AL.	Dustfall	
23	Mason Center 5000 George Mason Drive Arlington, Virginia	AR.	Dustfall	
			Rubber Cracking	Weighted Strip

TABLE B-I (continued). STATION SUMMARY

Station No.	Name and Address	Agency	Analyzer	Technique
24	Drew 1660 Fort Myer Drive Arlington, Virginia	AR.	Dustfall Sulfation Candle	PbO_2 Candle
25	Fish Exchange Building 1607 Jefferson Davis Highway Arlington, Virginia	AR.	Dustfall	
26	Gas Light Building 2700 Shirley Highway Arlington, Virginia	AR.	Dustfall	
27	Fairfax Library 3915 Chain Bridge Fairfax, Virginia	F.	Dustfall Sulfation Candle Rubber Cracking	PbO_2 Candle Weighted Strip
29	Westgate 6801 Fort Hunt Road Fairfax County, Virginia	F.	Dustfall Sulfation Candle Rubber Cracking	PbO_2 Candle Weighted Strip
30	Belvedere School 6540 Columbia Pike Fairfax County, Virginia	F.	Dustfall Sulfation Candle	PbO_2 Candle
31	Falls Church Bank 101 West Broad Street Falls Church, Virginia	F.	Dustfall	
33	C.A.M.P. 1st and L Streets, N.W. Washington, D. C.	D.C.	SO_2 OX	Conductivity - H_2O_2 (Beckman) Colorimetric - Neutral KI (Beckman)

TABLE B-I (continued). STATION SUMMARY

Station No.	Name and Address	Agency	Analyzer	Technique
			NO_2	Colorimetric - Saltzman (Beckman)
			NO	Colorimetric - Saltzman (Beckman)
			CO	Infrared (Beckman)
			HC	Flame Ionization (Beckman)
			Particulate	Hi-Vol
			Respirable Dust	Hi-Vol (cyclone pre-filter)
			Soiling Index	Smoke Shade AISI Tape Sampler
			Effects Package	
			Wind Speed	
			Wind Direction	
41	National Airport, Virginia	P.H.S.	Particulate	Hi-Vol
			Dustfall	
			Sulfation Candle	PbO_2 Candle
46	Seven-Corners Willston School Seven-Corners, Virginia	P.H.S.	SO_2	Colorimetric - West Gaeke Sequential
			OX	Coulometric - KI (Mast)
			Particulate	Hi-Vol
			Dustfall	
			Sulfation Candle	PbO_2 Candle
			Rubber Cracking	Weighted Strip
50-53	Silver Hill Tower Silver Hill, Maryland	E.S.S.A.	Temperature	
			Wind Speed	
			Wind Direction	
58	N.I.H. Bethesda, Maryland	P.H.S.	SO_2	Conductivity - H_2O_2 (Beckman)
			OX	Colorimetric - Neutral KI (Beckman)

TABLE B-I (continued). STATION SUMMARY

Station No.	Name and Address	Agency	Analyzer	Technique
			NO_2	Colorimetric - Saltzman (Beckman)
			NO_x	Colorimetric - Saltzman (Beckman)
			CO	Infrared (Beckman)
			HC	Flame Ionization (Beckman)
			Particulate	Hi-Vol
			Wind Speed	
			Wind Direction	
			Wind Sigma	
			Dustfall	
			Sulfation Candle	PbO_2 Candle
			Rubber Cracking	Weighted Strip
			Vegetation Chamber	
59	Suitland-Census Bureau Silver Hill at Suitland Road Suitland, Maryland	P.H.S.	SO_2	Conductivity - H_2O_2 (Beckman)
			OX	Coulometric - KI (Mast)
			CO	Infrared (Beckman)
			Particulate	Hi-Vol
			Soiling Index	Smoke Shade AISI Tape Sampler
			Wind Speed	
			Wind Direction	
			Wind Sigma	
			Dustfall	
			Sulfation Candle	PbO_2 Candle
			Rubber Cracking	Weighted Strip
60	Loudoun County 18 N. King Street Leesburg, Virginia	L.	Effects Package	

TABLE B-I.(continued). STATION SUMMARY

Station No.	Name and Address	Agency	Analyzer	Technique
65	Kenilworth Dump Thomas School Focte Street Washington, D. C.	P.H.S.	Particulate	Hi-Vol
66	U. S. Naval Station Washington, D. C.	P.H.S.	SO_2	Conductivity - H_2O_2 (Beckman)
			Dustfall Sulfation Candle Rubber Cracking	 PbO_2 Candle Weighted Strip
67	Prince William County Manassas, Virginia	P.W.	Dustfall Sulfation Candle Rubber Cracking	 PbO_2 Candle Weighted Strip
70-73	Tysons Corner Tower Tysons Corner, Virginia	E.S.S.A.	Temperature Wind Speed Wind Direction	
74	Calvert Mansion (Police Station) Riverdale, Maryland	P.H.S.	Vegetation Chamber	
75	George Washington Monument Washington, D. C.	P.H.S.	Vegetation Chamber OX	 Coulometric - KI (Mast)
76	Paint and Varnish Assn. 1500 Rhode Island Avenue Washington, D. C.	P.H.S.	Soiling Index	Smoke Shade• AISI Tape Sampler
77	South Agricultural Building 12th and C Streets, S.W. Washington, D. C.	P.H.S.	SO_2	Conductivity - H_2O_2 (Beckman)
78	Park Police (Park Service) Ohio Drive Washington, D. C.	D.C.	Effects Package	

TABLE B-I (continued). STATION SUMMARY

D. C. - District of Columbia
P.H.S. - Public Health Service
AL. - Alexandria City, Virginia
F. - Fairfax County, Virginia
L. - Loudoun County, Virginia
E.S.S.A. - Environmental Science Services Administration

P.G. - Prince Georges County, Maryland
M. - Montgomery County, Maryland
AR. - Arlington County, Virginia
C.A.M.P. - Continuous Air Monitoring Program
P.W. - Prince William County, Virginia

RUBBER CRACKING

A rubber cracking network was initiated to serve as indicators of oxidant concentration in the study area and to provide a correlation with OX automatic monitoring instruments. A total of 11 rubber strips were located in the study area. Five more were located at the effects station sites.

The rubber strips were weighted and exposed for 7 days in small shelters. The cracks were then counted and measured in the laboratory.

DUSTFALL

A network of 31 dustfall recepticals was established to determine the settleable dust rates in the study area. An additional five recepticals were located at the effect station sites.

The 31 recepticals were prepared and analyzed by the Metropolitan Washington Council of Governments.

SUSPENDED PARTICULATE

Eighteen high-volume filter samplers were located in pairs at nine major air monitoring stations in the study area to measure suspended particulates. Locations are shown in Table B-1. Each sampler was electrically programmed to operate from midnight to midnight, on a 24-hour-on, 48-hour-off schedule; thus, each pair of samplers sampled 2 days of each 3-day period.

Total suspended particulate was collected on 8- by 10-inch glass fiber filters over 24-hour periods. Results were based on differences between the tare weight and final gross weight of each filter and volume of air sampled. Data are reported as micrograms of total particulate per cubic meter of air.

SPECIAL SAMPLING

Supplemental air monitoring data were obtained from special sampling activities initiated in the Washington, D.C., area air pollution abatement investigation. The activities are listed and discussed.

A special SO_2 traverse project was conducted to determine the SO_2 concentrations in areas close to selected point sources. Heating plants were of primary interest.

CALIBRATION OF MONITORING STATIONS

The accuracy and validity of the study data are dependent upon the type and extent of its quality control.

During the month of May 1967, static and dynamic calibration techniques were used by Public Health Service personnel at stations of the continuous monitoring network to calibrate all instruments analyzing for SO_2, NO_2 or NO_x, CO, total oxidants, and total hydrocarbons.[B3] Instrument acceptability required an accuracy within ± 10 percent of results from manual analyses. All instruments were found to be within this acceptable range at the time of calibration.

REDUCTION OF WIND SPEED AND DIRECTION DATA (NIH, ALEXANDRIA, SUITLAND, AND CAMP)

Hourly average wind speed was determined from strip-chart records of wind speed. The "equal area" method was used to extract and tabulate data to the nearest mile per hour. This method is a visual inspection technique by which a value of the wind speed that divides the oscillations of the wind trace into equal areas is selected from each time increment - in this case, 1 hour. The value selected was considered the mean speed for the hour. Speeds less than 0.5 mile per hour were tabulated as calm. Calms and missing and doubtful data were appropriately indicated on tabulations for computer processing. Corrections were applied, if appropriate, for drift of the recording and sensing system from zero.

Hourly average wind direction was determined from record traces of the direction. A representative wind direction was ascertained for each hour by the "equal area" method described above. Calms and missing and doubtful data were appropriately noted on tabulation forms.

PERSONNEL

The Aerometry Unit consisted of three full-time personnel: the unit chief, senior engineer, and one engineering technician. Additional part-time help was provided during the summer months by a student.

The unit chief was responsible for overall supervision and coordination of routine and special air quality measurement activities. The senior engineer supervised operations of Public Health Service stations and special sampling activities. The senior engineer was also responsible for laboratory support, including analyses and preparation of apparatus, equipment and chemical reagents. The engineering technician serviced the five Public Health Service stations and collected the samples. The technician inspected the equipment daily to ensure that all systems were operating properly. The part-time students participated in a variety of activities, including the plant exposure program, data processing, and general maintenance of equipment.

FIELD SERVICING OF STATIONS

The size and complexity of the aerometry program required the establishment of standard operating procedures for each subphase of the program, e.g., calibration and servicing automatic instrumentation, changing lead peroxide candle samples and suspended particulate sampling. A summary of a typical month's scheduling for Public Health Service stations illustrates daily, weekly, and monthly activities.

DAILY

1. All automatic instrumentation sites were visited. Reagents were added to the instruments as required. Instrument operations were checked and changes made as needed. All data charts were checked and any abnormalities noted. Malfunctions of equipment were detected and corrected.

2. High-volume filter samplers were serviced as needed. Generally, these samplers required attention only about once in 3 days.

3. The plant exposure chambers were visited every day during the plant study to keep the plants watered and nourished, and to provide surveillance of plant damage.

WEEKLY

1. The data strip charts from the automatic instrumentation were cut and returned to the survey field station. These charts were then validated and forwarded to Cincinnati for processing.

2. A weekly preventative maintenance schedule was followed with all automatic instruments.

3. Plant pots in the exposure chambers were flushed with distilled water to prevent buildup of salts in the support media. Fresh nutrient was added each week. Hygrothermograph charts in the plant chambers were changed weekly.

4. The 11 rubber cracking stations were visited and the strips changed.

MONTHLY

1. Automatic wet-chemistry units were completely dismantled, cleaned, reassembled, and statically calibrated.

2. The 21 lead peroxide candle stations were visited and the candles changed.

3. Air flow volumes for high-volume filter samples were calculated.

4. The 31 dustfall receptical stations were visited and the recepticals changed. Various programs such as calibration, grab sampling, and equipment maintenance and repair were conducted throughout the month as permitted.

Appendix B REFERENCES

B1. Foster, K.E., Brooman, D.L. and Humphrey, P.A., "Integration of Air Monitoring, Meteorological, and Data-Logging Units into a Mobile Air Sampling Station." Presented at the 59th Annual Meeting of the Air Pollution Control Association, San Francisco, California, June 20-24, 1966.

B2. Hochheiser, S., "Methods of Measuring and Monitoring Atmospheric Sulfur Dioxide." PHS Publ. No. 999-AP-6, U.S. Department of Health, Education, and Welfare, Division of Air Pollution, August 1964.

B3. Christman, D.F., and Foster, K.E., "Calibration of Automatic Analyzers in a Continuous Air Monitoring Program." Presented at the Annual Meeting of the Air Pollution Control Association, Detroit, Michigan, June 20, 1963.

APPENDIX C. EMISSIONS INVENTORY PROCEDURE

Various means were used to quantify the pollutants (sulfur oxides, nitrogen oxides, carbon monoxide, particulates, and hydrocarbons) released from sources in the study area. Where emissions were of significant magnitude, efforts were made to obtain exact figures, usually by direct interview. For the vast number of small sources - automobiles, trucks, medium to small residences, and small industrial, commercial, and governmental establishments - it was not possible to contact each source separately. To obtain accurate figures on the latter categories, it was necessary (1) to employ traffic study data and census figures on population, dwelling units, and manufacturing and commercial operations and (2) to ascertain fuel usage by typical users in the area from local sources and publications.

The initial data for the report were compiled during the 2-month period from February through March 1967. The Public Health Service rapid survey technique for emission inventories was used.[1] The inventory consisted of evaluating the consumption of gasoline, diesel fuel, coal, fuel oil, and natural gas and of determining emissions from refuse incineration, process industries, auto burning, aircraft flights, and evaporative losses. Emissions were determined directly from the fuel input to the equipment for both automotive and stationary sources. Control equipment was also taken into account for emissions from coal combustion and process sources. Emission factors and average sulfur and ash contents are listed in Table C-1. The general emission factors used were obtained from Public Health Service and New York State publications[2,3] and from various PHS staff estimates.

Annual consumption of all fuels and annual process emissions in each zone were determined for the years 1965 and 1966. Daily emissions were calculated for minimum, average, and maximum space-heating days and reported as tons of pollutant per square mile.

POINT SOURCES

Each residential site, governmental or commercial building, industrial site, large incinerator, etc., from which 100 or more tons of any single pollutant were emitted per year was considered a point source. There were 99 such sources in the area.

MOBILE SOURCES

The principal sources of oxides of nitrogen, carbon monoxide, and hydrocarbons are from mobile sources. The greatest percentages of these totals of course come from the combustion of motor fuel by gasoline and diesel-powered vehicles.

Table C-1. GENERAL EMISSION FACTORS
WASHINGTON, D. C. AIR POLLUTION ABATEMENT ACTIVITY, 1965-66
(tons/unit[a])

Source	SO_x	NO_x	Particulate	CO	HC
Residual oil (1,000 hp or more)	0.203[b]	0.052	0.004	Neg.	0.0016
Residual oil (1,000 hp or less)	0.203[b]	0.036	0.006	0.001	0.001
Distillate oil (1,000 hp or more)	0.024[b]	0.052	0.004	Neg.	0.0016
Distillate oil (1,000 hp or less)	0.024[b]	0.036	0.006	0.001	0.001
Anthracite coal (residential)	0.011[b]	0.004	0.010[c]	0.025	0.005
Anthracite coal (Commercial, Governmental)	0.011[b]	0.004	0.025[c]	0.025	0.005
Bituminous coal (Residential, commercial, Governmental)	0.019[b]	0.004	0.018[c]	0.025	0.005
Bituminous coal (industrial)	0.019[b]	0.010	0.018[c]	0.002	0.0005
Natural gas (Residential, commercial, Governmental)	0.0002	0.058	0.010	0.0002	Neg.
Natural gas (industrial)	0.0002	0.107	0.009	0.0002	Neg.
Gasoline	0.004	0.057	0.005	1.455	0.262
Diesel oil	0.020	0.111	0.055	0.030	0.090
Aircraft	(d)	(d)	(d)	(d)	(d)
Open-burning dump	0.0006	0.0003	0.024	0.043	0.040
Municipal incinerator	0.001	0.001	(e)	0.0004	0.0007
Residential, commercial, Governmental, industrial incineration	0.0002	0.0008	0.010	0.013	0.018
Backyard paper burning	0.0006	0.0003	0.002	-	0.073
Gasoline evaporation	-	-	-	-	0.060
Solvent losses (dry cleaning)	-	-	-	-	1.95

[a] Fuel oil, gasoline, and diesel fuel, 1,000 gallons; coal, tons; natural gas, 10^6 cubic feet; refuse, tons; dry cleaning, 1,000 people.

[b] Dependent on sulfur content of fuel: residential oil, 2.55% S; distillate oil, 0.3% S; anthracite coal, 0.6% S; bituminous coal, 1.0% S.

[c] Dependent on ash content of coal, type of firing unit, and type of control: anthracite coal, 10.0% A; bituminous coal, 7.0% A.

[d] Dependent on type of aircraft, see References 2 and 11 of this appendix.

[e] Dependent on type of control; see Reference 2 of this appendix.

GASOLINE AND DIESEL FUEL USAGE

To determine the amount of gasoline used in the area, it was necessary to obtain state-wide gasoline sales.[4] A proportion of these sales for Maryland and Virginia were then distributed to the various political subdivisions in the states on the basis of service station sales.[5] It was assumed that the ratio of gasoline sales to total service station sales is constant within the states; thus a direct ratio may be used.

Gasoline sales in county or city=

$$\frac{\text{service station sales in county or city (\$)}}{\text{service station sales in state (\$)}} \times \text{gas sales in state (gal.)}$$

The gasoline consumption for the District of Columbia was directly listed in a publication.[4]

It was then estimated that any gasoline sold in a specific county or city was consumed there, which assumes that the inflow of gasoline into the county or city equals the outflow.

To determine the amount of gasoline consumed in each zone, a percentage of the gasoline for the county or city was based on traffic counts, vehicle miles,[6,7,8] type of road, and average vehicle speed.[9]

The consumption of diesel fuel in the study area is minor by comparison with consumption of gasoline. Diesel fuel sales were available for the District of Columbia,[4] but were estimated for the surrounding counties and cities from the ratio of diesel to gasoline usage in the District. In most cases, a smaller fraction was used because of less-dense truck traffic. The estimate of diesel consumption in each emission zone was then made, using the same percentages of the total as was used for gasoline consumption.

In addition to the pollutant emissions from the actual operation of a motor vehicle, there are hydrocarbon losses due to the transfer of fuel from: (1) storage to tank truck, (2) from tank truck to filling station, and (3) from filling station to motor vehicle tanks. Evaporative losses from the motor vehicle gas tank and carburetor were also considered. A standard emission factor was applied to the total gasoline sales in the area to account for the hydrocarbon losses listed above (Table C-1).

RAILROAD DIESEL USAGE

The diesel fuel usage by railroads for the District of Columbia in 1965 is published in Petroleum Facts and Figures.[10] This amount of diesel fuel was then proportioned to the various zones by railroad track length and size of terminals and switching yards.

The estimates of railroad diesel fuel use by emission zone in the outlying counties and cities were based on the fuel per length of railroad track calculations made for the District.

AIRCRAFT

The pollutant emissions from aircraft operations were estimated from data supplied by the Federal Aviation Agency and Andrews Air Force Base. These data included numbers of takeoffs and landings by the various types of commercial and itinerant planes. Emission factors[2,11] were then applied per aircraft flight depending on the type and number of engines on the plane in question.

PROCESS SOURCES

Emissions from industrial processes (asphalt and concrete batch operations, foundries, and coffee roasting) were determined from plant visits and information solicited from company officials. Sources were selected for investigation by type of industry from local and national industrial directories. Included in this category are the hydrocarbon emissions from evaporative losses, such as from dry cleaning and solvent operations, and printing establishments.[30] In most cases the process emissions were estimated by Public Health Service engineers since no stack data or company estimates were available from plant officials.

REFUSE DISPOSAL

The amount of refuse disposed of in the study area was estimated on the basis of information gained from local officials and supervisory personnel at landfills, open-burning dumps, municipal incinerators, and auto-burning sites and on-site commercial, governmental, industrial, and residential incinerators.

The above surveyed types of disposal accounted for the greater part of the estimated refuse generated in the study area (1400 pounds per capita per year).[12]*
The difference between the refuse surveyed and that assumed to be generated in the area was estimated to be on-site incineration and backyard burning of paper and brush.

To allow for that part of the refuse that is not combustible, it was assumed that 40 percent of the difference in rural areas is open-burned in backyard burning barrels; in urban areas 20 percent of the difference is incinerated and 10 percent is open-burned. This latter estimate takes into account the more complete refuse pickup in urban areas compared to that in rural areas and also the usual bans against open burning in city areas. Emission calculations on surveyed refuse disposal practices took into account type of disposal and control equipment. The emission factors used for these calculations are found in PHS[2,13] and New York State publications.[3]

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*The estimate can run anywhere from less than 4 pounds up to 5 pounds of refuse per capita per day.

COMBUSTION FUELS

Sources were delineated in terms of fuel type and user types to determine the quantity of the various combustion fuels burned during different times of the year. Anthracite and bituminous coal, distillate and residual oil, and natural gas are the only fuels used in significant quantities in the study area. Fuel sources were listed as residential, Federal Government, commercial and other governmental, industrial, and steam-electric power plants. Residential sources included all dwellings from one-family homes to multistory high-rise apartment buildings.

The portion of fuel burned for space heating and that burned on a steady day-to-day basis throughout the year were determined. Essentially all commercial and governmental fuel, much residential fuel, and some industrial fuel were burned for space-heating purposes. The steam-electric plants in the area vary as to whether they fire at a constant daily rate or they are peak-service plants. The operating characteristics of each plant were taken into account in the calculation of daily emissions. The variable use of fuel for space heating determines the differences in emissions on minimum, average, and maximum space-heating days.

The fuel totals for the area broken down by county and city were determined by various methods, depending on the fuel type and source category. Overall totals were obtained from local fuel dealers,[14,15] natural gas suppliers,[16,17] local public utility officials,[27,28] national and local publications,[18,19,20,21] and Public Health Service personnel.[22]

RESIDENTIAL FUEL USAGE

Fuels consumed by residential sources were determined from information available on population; dwelling units; and the relative use of coal, oil and natural gas.[23,24,25] Smaller residential units were assumed to use natural gas, distillate oil, or anthracite coal for heating. Larger apartment buildings, i.e., 50 units or more, that used coal or oil were assumed to use residential fuel oil or bituminous coal.

POPULATION AND DWELLING UNITS

1965 Census data for counties and large cities are listed in the Rand McNally Commercial and Marketing Guide - 1966 Edition. Also available from local publications were 1965 population and dwelling unit estimatesfor many census tracts in the study area. Along with the above data and the 1960 census and dwelling unit data by census tract,[23,25,26] it was possible to update all census tracts in the study area to 1965 figures for population and dwelling units. The census tract data was then transferred to the emission zones.

Dwelling units built since 1960 were assumed to use either natural gas or oil. Depending on the location and type of residential area, i.e., single-family or multi-family complexes, it was assumed either 90 percent gas and 10 percent oil, 20 percent gas and 80 percent oil, 60 percent gas and 40 percent oil, or 40 percent gas and 60 percent oil were used by the new dwelling units.

RESIDENTIAL USE OF COAL

The number of area-wide occupied dwelling units using coal in 1960 was developed by the Public Health Service using Bureau of the Census data.[24] These data list by census tract those dwellings using coal for heating purposes. It was assumed that all coal used for residential purposes is anthracite.[1] Only those large apartment complexes that were found to use bituminous coal in a survey were included in the inventory. Based on degree-days and rooms per unit, the amount of coal per dwelling unit used for heating purposes in each political subdivision is shown in Table C-2.[2] It was assumed that all coal used residentially was only for space heating.

Table C-2. AVERAGE SPACE-HEATING FUEL USAGE FOR RESIDENTIAL DWELLING UNITS

	Coal, tons/yr.	Oil, gal/yr.	Natural gas, $ft^3/yr.$
District of Columbia	4.0	650	77,000
Montgomery County	6.3	925	115,000
Prince Georges County	5.5	800	100,000
Arlington County	4.5	725	90,500
Fairfax County	6.0	900	115,000
Loudoun County	6.0	900	115,000
Prince William County	5.0	760	95,000
Alexandria City	4.5	725	90,500
Fairfax City	6.0	900	115,000
Falls Church City	6.0	900	115,000

A 1965 estimate of anthracite coal use based on population was made for each political subdivision from state-wide distribution as reported by the Bureau of Mines.[20] It was assumed that the greatest percentage of anthracite coal was used residentially. Based on these 1965 estimates and local sources of information, it was necessary to reduce the number of dwelling units thought to have been using coal in 1960. The dwellings using coal in each emission zone were reduced in proportion to the decrease in residential coal usage in the area from 1960 to 1965. Dwelling units that no longer heat with coal were assumed to have switched to natural gas.

RESIDENTIAL USE OF OIL

The number of 1960 area-wide units burning fuel oil for heat was determined in the same manner as the number burning coal. The 1965 total of dwelling units using fuel oil for heating was obtained by adding to the 1960 totals the percentage of the new dwellings that were assumed to be using fuel oil.

Residential structures of more than 50 dwelling units that use fuel oil were assumed to use residual oil. From data in the 1960 Census of Housing,[25] it was possible to estimate the total number of dwelling units in structures of 50 or more units.

Table C-2 lists the estimated fuel oil used by an average dwelling unit using fuel oil for heating. For every unit using distillate oil for heating purposes, 250 gallons per year of distillate oil was assumed to be consumed for water-heating, air-conditioning, and cooking purposes. For those units using residual oil, it was felt that the initial estimates (as shown in Table C-2) also included the oil used for water heating, air conditioning, and cooking. The amount of residual oil used for non-space-heating purposes was also estimated to be 250 gallons per year. This smaller use of residual oil per dwelling unit takes into account the fact that less heating is required per dwelling unit in large apartment houses than in smaller buildings.

RESIDENTIAL USE OF NATURAL GAS

The number of dwelling units using natural gas for heating purposes was determined from the 1960 Census in the same manner as that described for coal and fuel oil. Up-dating these data to 1965 was accomplished by adding to the 1960 figures the percentage of the new dwelling units built since 1960 that were estimated to be using natural gas for heating.

Table C-2 lists the estimated natural gas used by a residential dwelling unit using natural gas for heating. Actual usage totals furnished by natural-gas suppliers[16,17] for each political subdivision in the area indicated larger overall figures than can be estimated from the data listed in Table C-2. These larger figures reflect the natural gas used for water heating and cooking, not only in the natural-gas-heated homes, but also in those homes heated with coal or oil. This differential amount of gas was allotted to the emission zones in proportion to the number of dwelling units using gas for heating. This estimate can be made since there is probably a reasonably equal distribution of both types of natural-gas users in the emission zones.

FEDERAL, COMMERCIAL, AND OTHER GOVERNMENTAL FUEL USE

All Federal, state, and local governmental agencies and large private institutions were surveyed through interviews and information from local fuel dealers[14,15] and natural-gas suppliers.[16,17] The fuel data and control equipment information obtained from these known sources were used to estimate their emissions and to determine whether they should be considered as point sources. These fuel-use data and the resulting emissions were placed in the emission zones corresponding to the location of the source in question.

The homogeneous coal and oil usage by commercial and governmental establishments was determined as the difference between estimated totals for each political subdivision and the surveyed fuel as listed above. The commercial and governmental coal and oil totals for each political subdivision were estimated from Bureau of Mines data for Virginia, Maryland, and the District of Columbia.[18,19] The estimates for each political subdivision were based on a population and commercial proportioning basis. The surveyed coal and oil were then subtracted from the above overall totals, and the difference was apportioned to the emission zones based on knowledge of the area, U. S. Geological Survey topographical maps, land-use maps, and information procured from local officials. Natural-gas data were supplied by gas utilities[16,17] and apportioned in the same manner.

INDUSTRIAL FUEL USE

Industrial users considered to be possible point sources were contacted. The fuel data, along with their process emissions, were used to determine whether they would be considered point sources. The emissions and fuel data were placed in the proper emission zone corresponding to the location of the plant in question.

It was also necessary to estimate the amount of fuel used by the smaller industrial sources not surveyed. State-wide data for industrial use of oil and coal in Virginia, Maryland, and the District of Columbia were obtained from Bureau of Mines[19] and Census Bureau publications.[21] These data were then proportioned to the political subdivisions of the area according to the number of manufacturing employees.[29] Natural-gas usage by industrial consumers was obtained from the gas utilities.[16,17] In each political subdivision the surveyed fuel data were subtracted from the estimates for the total subdivision. The remaining homogeneous background figure was then distributed over the emission zones within the county in proportion to the degree of industrialization. U. S. Geological Survey topographical maps, land-use maps, and knowledge of the area were used to estimate the degree of industrialization in each zone.

STEAM-ELECTRIC POWER PLANTS

Fuel-use figures were obtained directly from the utilities in the study area.[27, 28] Amounts of fuel oil, bituminous coal, and natural gas used at all power-generating stations were provided together with sulfur, and ash contents, type of firing units, control equipment, and seasonal variation in operating characteristics.

DAILY VARIATIONS IN POLLUTANTS RESULTING FROM SPACE HEATING

Pollutant emissions were determined for minimum, average, and maximum space-heating days. For each zone, the emissions were divided into a variable fraction resulting from space heating and a steady fraction resulting from operations that are essentially constant throughout the year. The variable emissions were assumed to consist of:

1. All commercial and governmental emissions.
2. 25 percent of the industrial fuel emissions.
3. A portion of the residential fuel emissions (see previous section on residential fuel burning).
4. Emissions from those steam-electric power plants that are peak loading stations.

Steady day-to-day emissions consist of:

1. All process emissions.
2. 75 percent of the industrial fuel emissions.
3. A portion of the residential fuel emissions, i.e., those emanating from cooking and water heating (see previous section on residential fuel burning.
4. All refuse disposal emissions.
5. All mobile source emissions.
6. Emissions from those steam-electric power plants that have constant daily loadings.

Average and maximum space-heating-day totals were determined by adding steady emissions to variable emissions during respective days. Meteorological data acquired from the U. S. Weather Bureau were used to determine these fractions of the yearly variable pollutants emitted during average and maximum space-heating days. The following formulas were used to calculate daily emissions:

Minimum space-heating day = steady emissions,

$$\text{Average space-heating day} = \text{minimum} + \text{variable emissions, tons/year} \; \frac{(19)}{(4365)}$$

$$\text{Maximum space-heating day} = \text{minimum} + \text{variable emissions, tons/year} \; \frac{(46)}{(4365)}$$

The factor 19/4,365 represents the fraction of annual degree-days occurring on the average heating day. The value 19 is the mean degree-days for all days of the year with an average temperature less than 65°F; the value 4,365 is the cumulative degree-days for the year 1965. The factor 46/4365 represents the fraction of annual degree-days occurring on coldest days; the value 46 is the normalized average degree days for the 4 coldest days of the year. Daily tonnages were divided by the zone areas to yield emission concentrations in terms of emissions per square mile.

APPENDIX C REFERENCES

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Appendix D

This appendix contains tables and figures pertinent to the Technical Report. Included are the following:

1. Frequency distributions of daily suspended particulate concentrations.
2. Frequency distributions of daily respirable dust concentrations.
3. Frequency distributions of two-hour soiling index.
4. Frequency distributions of hourly sulfur dioxide concentrations.
5. Frequency distributions of daily sulfur dioxide concentrations.
6. Frequency distributions of hourly carbon monoxide concentrations.
7. Frequency distributions of hourly oxidant concentrations.
8. Frequency distributions of hourly nitrogen dioxide concentrations.
9. Frequency distribution of hourly hydrocarbon concentrations.
10. Emission inventory data by county and emission zone.
11. Emission inventory zone map.

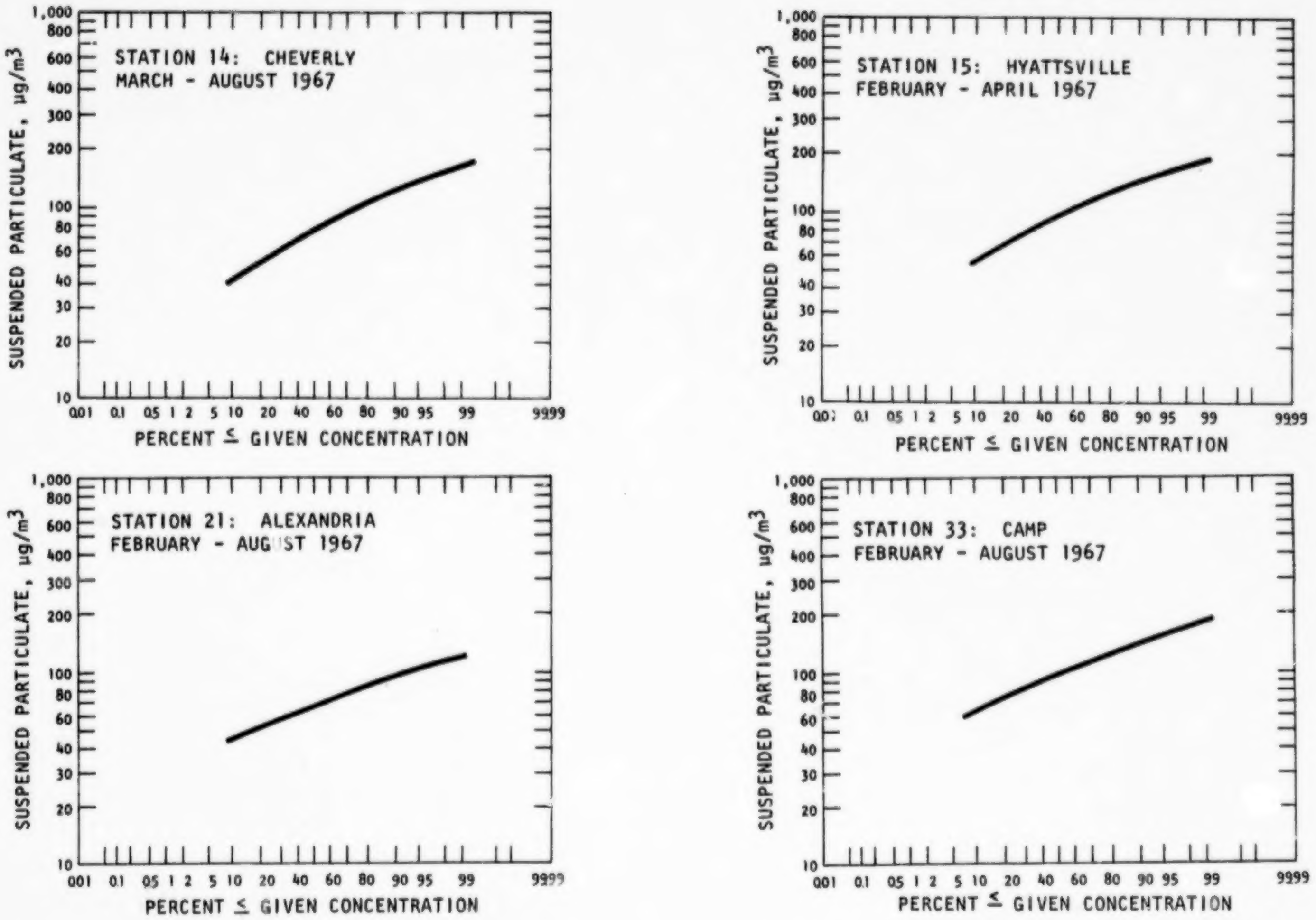

Figure D-1. Daily suspended particulate cummulative frequency distribution for stations 14, 15, 21, and 33.

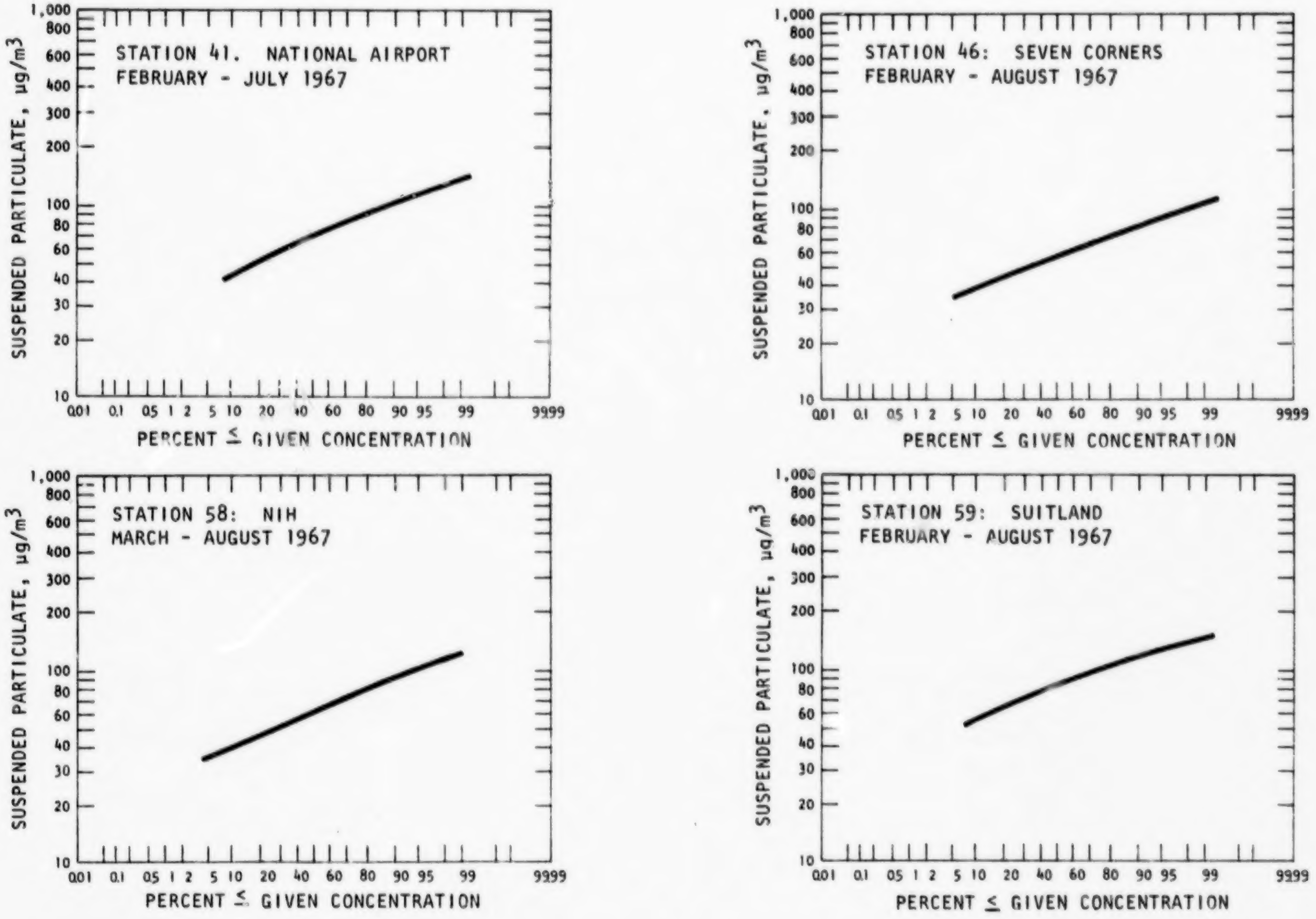

Figure D-2. Daily suspended particulate cummulative frequency distribution for stations 41, 46, 58, and 59.

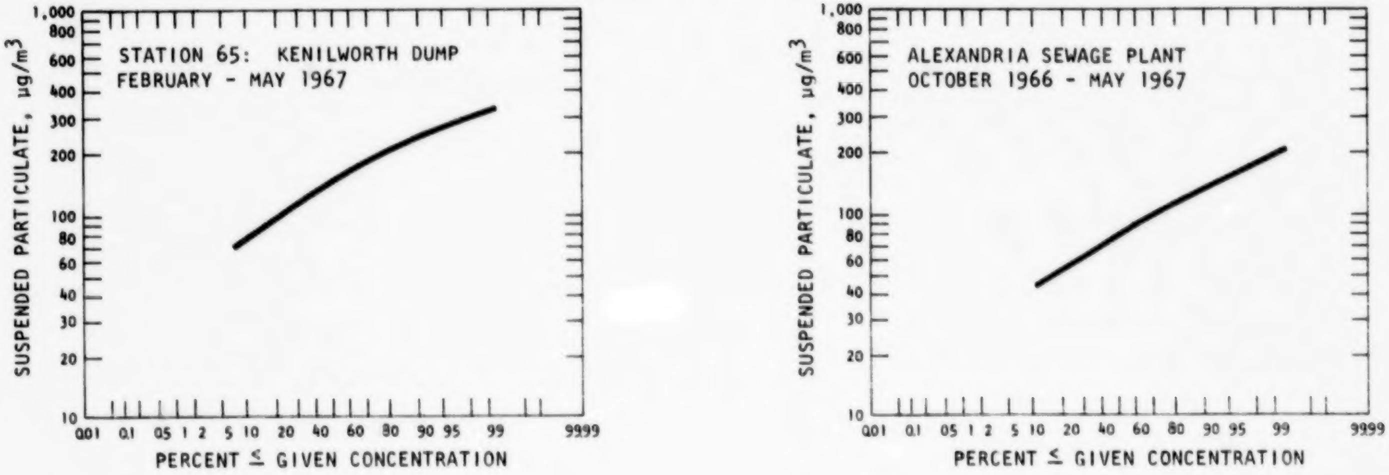

Figure D-3. Daily suspended particulate cummulative frequency distribution for stations 65 and Alexandria sewage plant.

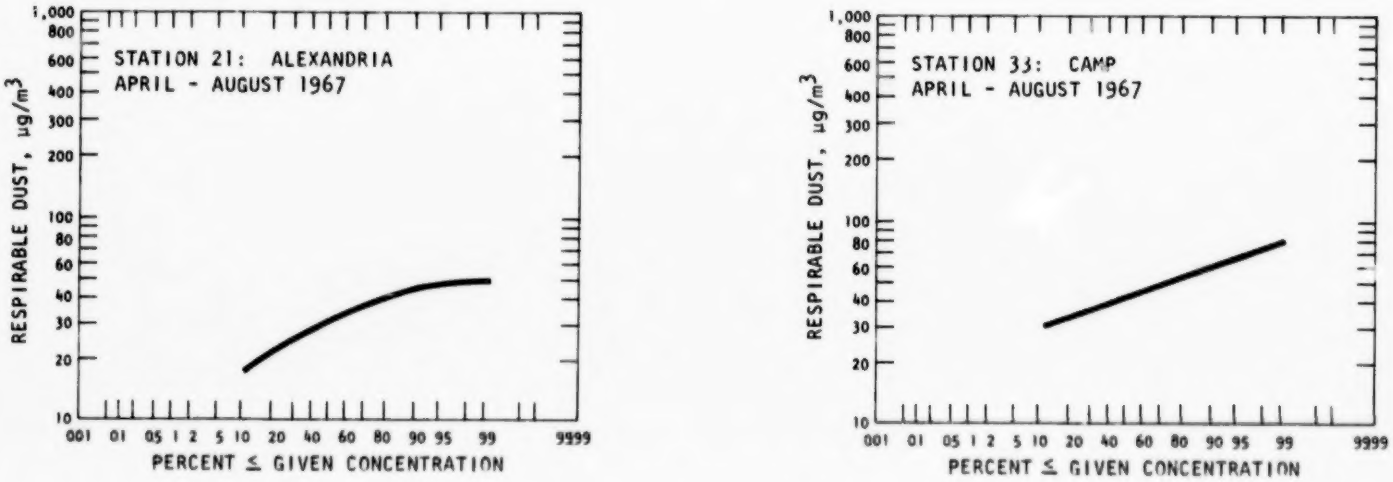

Figure D-4. Daily respirable dust cummulative frequency distribution for stations 21 and 33.

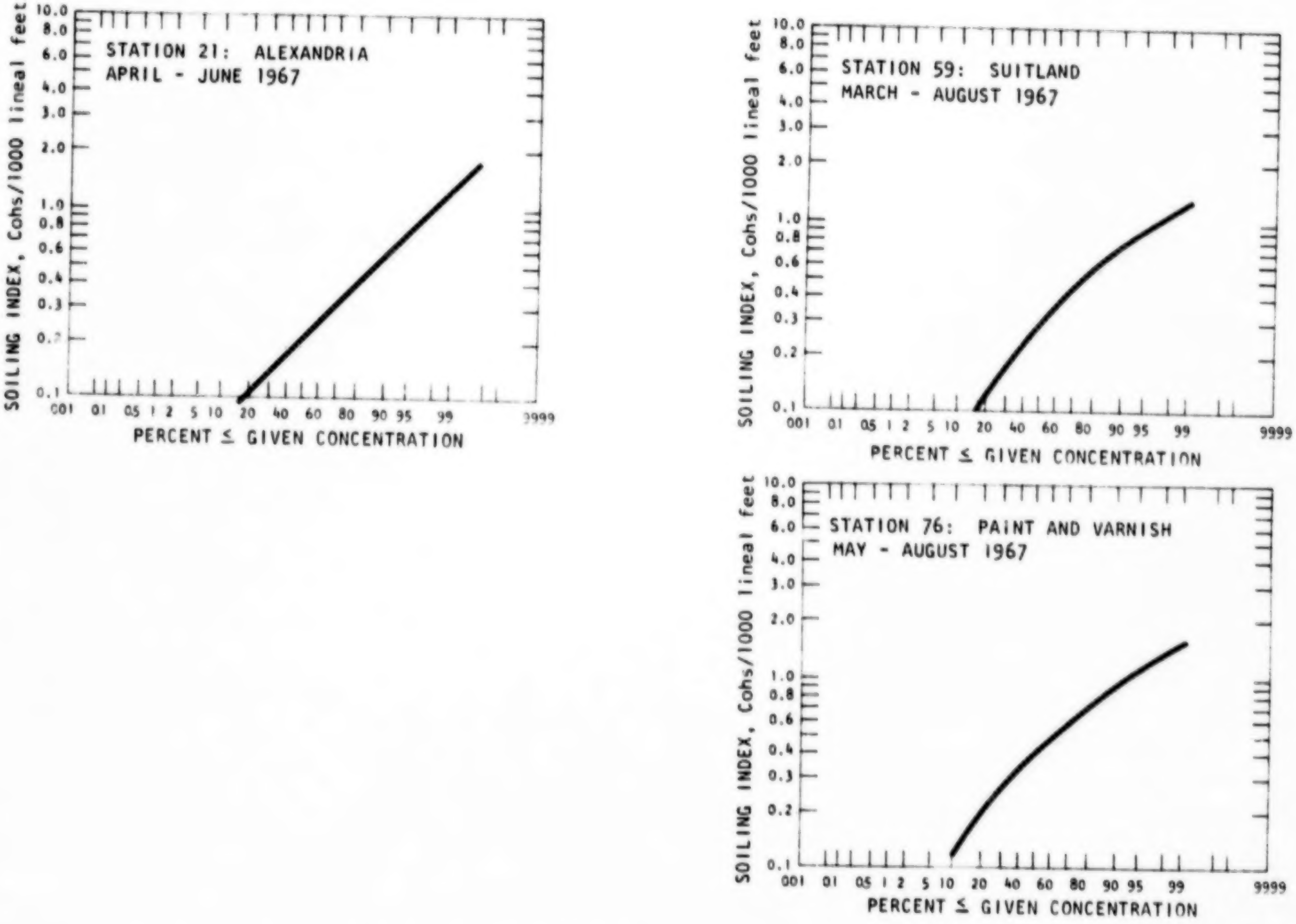

Figure D-5. Two-hour soiling index cummulative frequency distribution for stations 21, 59, and 76.

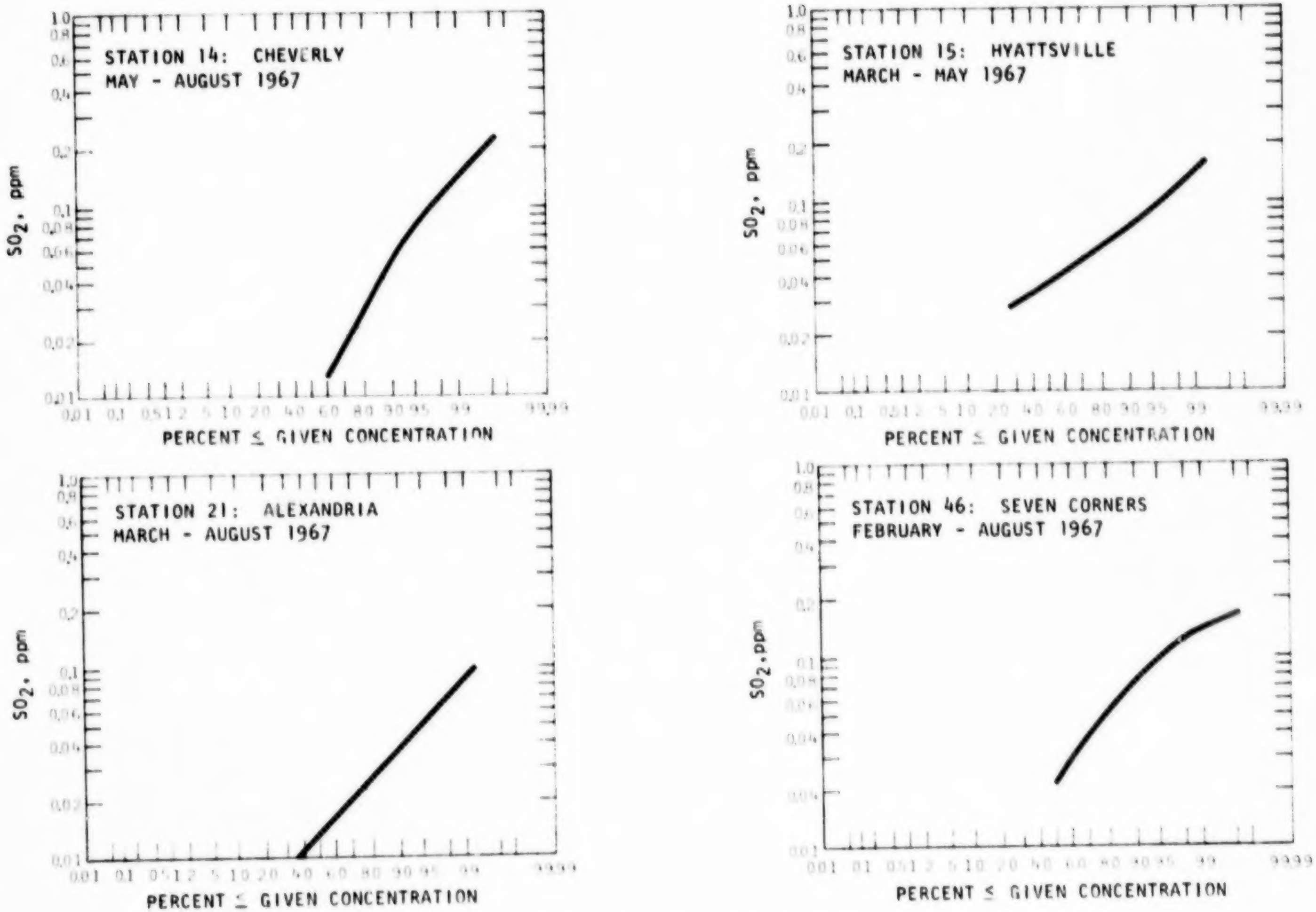

Figure D-6. Hourly average SO_2 cummulative frequency distribution at stations 14, 15, 21, and 46.

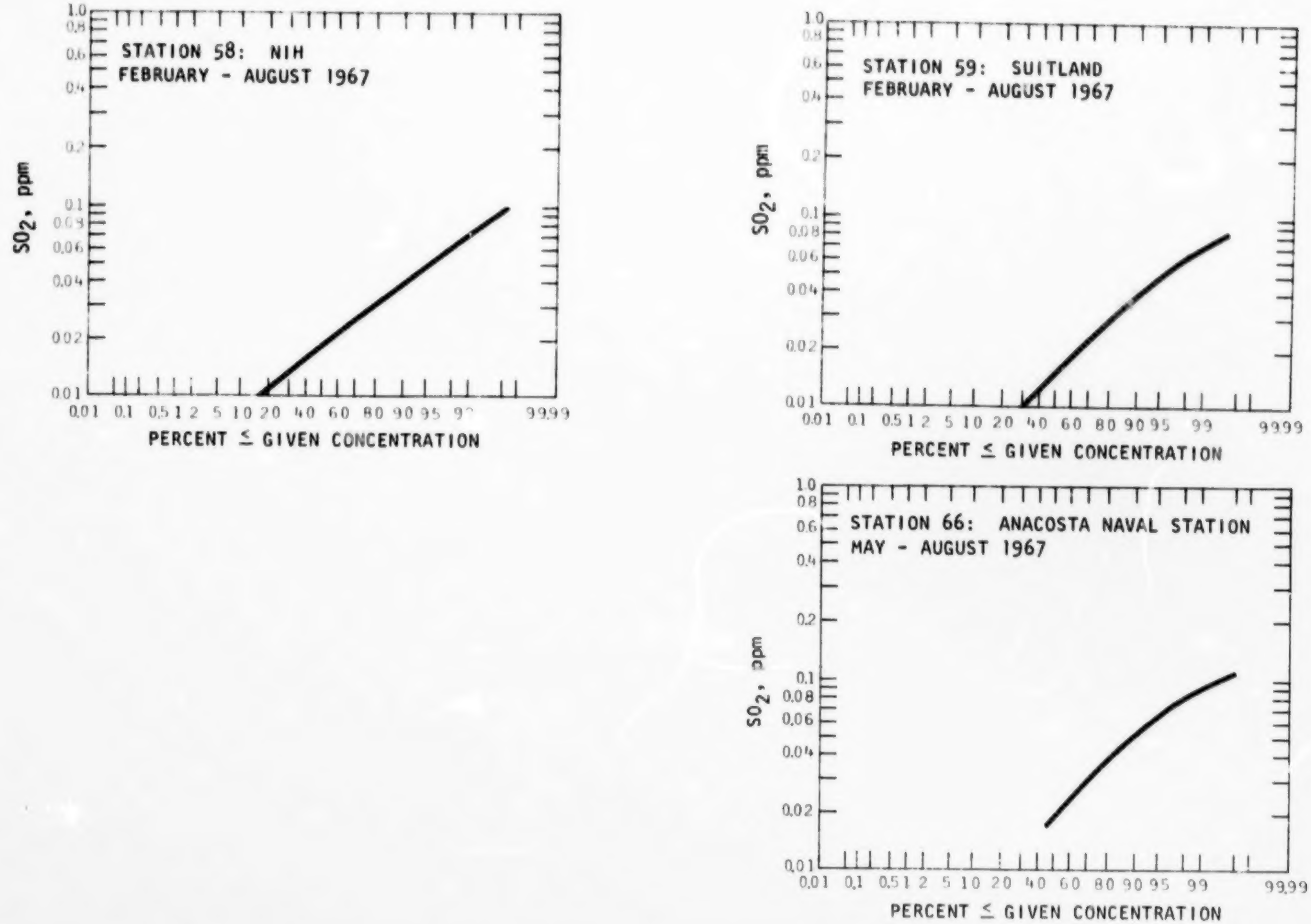

Figure D-7. Hourly average SO_2 cummulative frequency distribution at stations 58, 59, and 66.

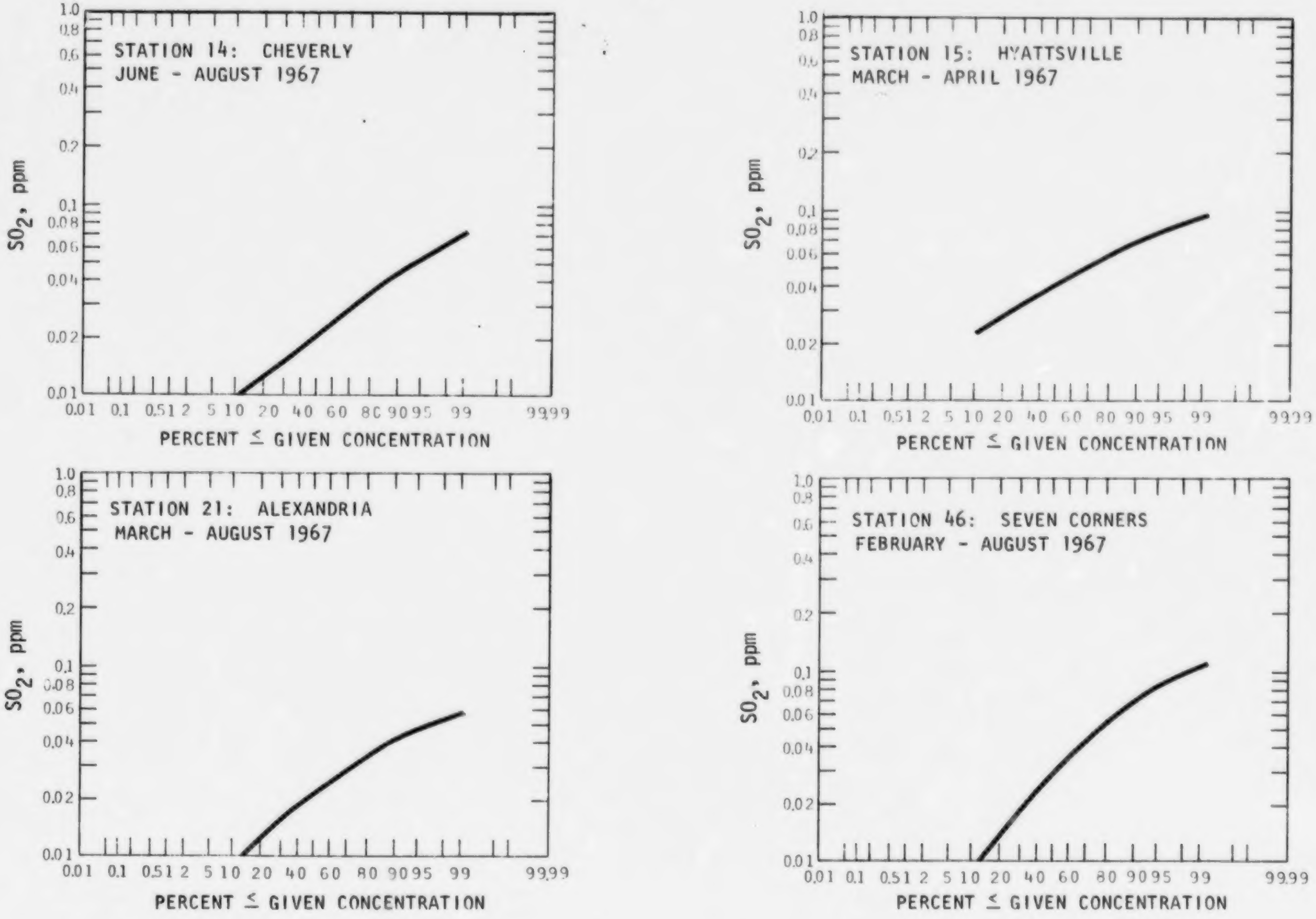

Figure D-8. Twenty-four-hour average SO_2 cummulative frequency distribution at stations 14, 15, 21, and 46.

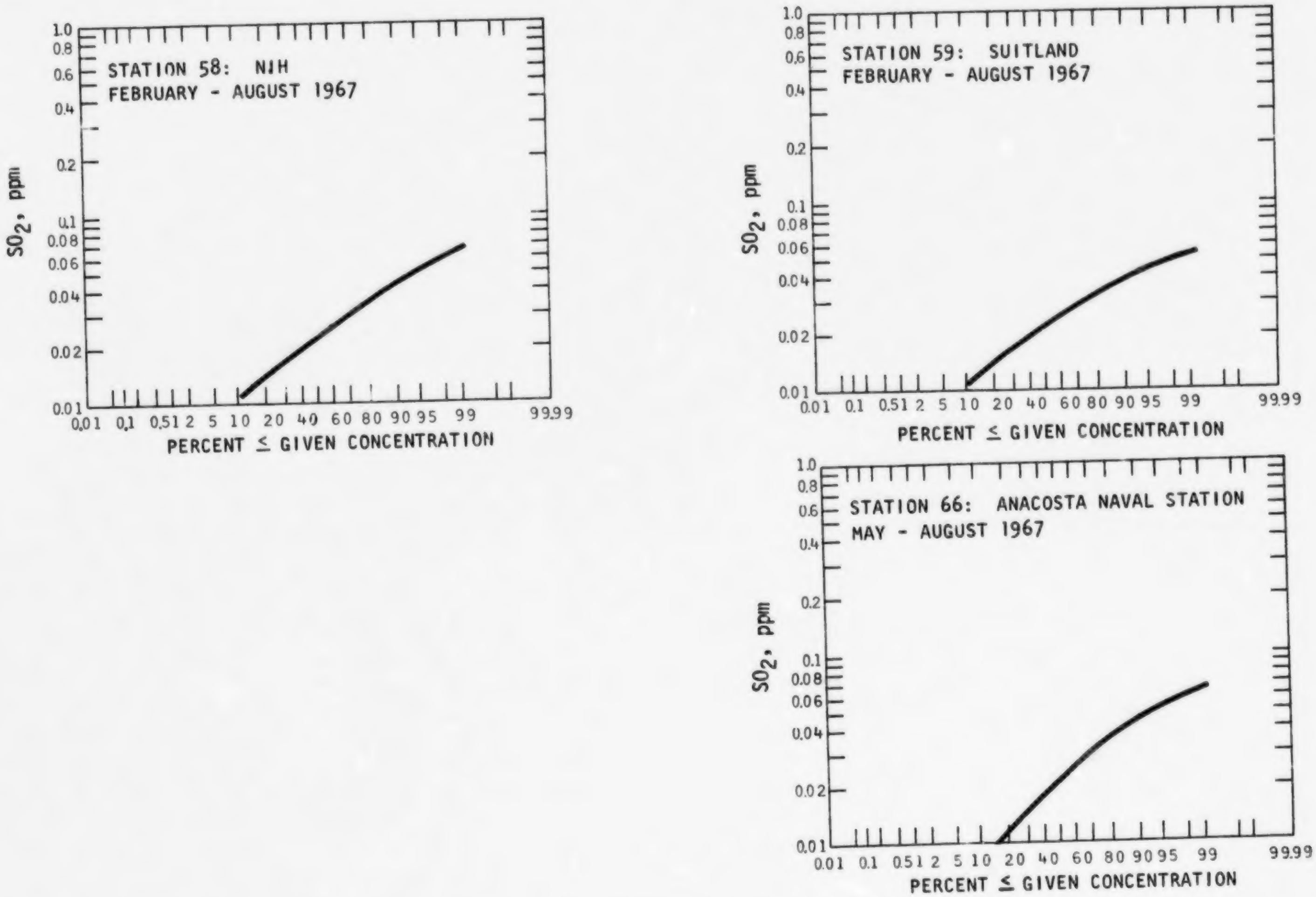

Figure D-9. Twenty-four-hour average SO$_2$ cummulative frequency distribution for stations 58, 59, and 66.

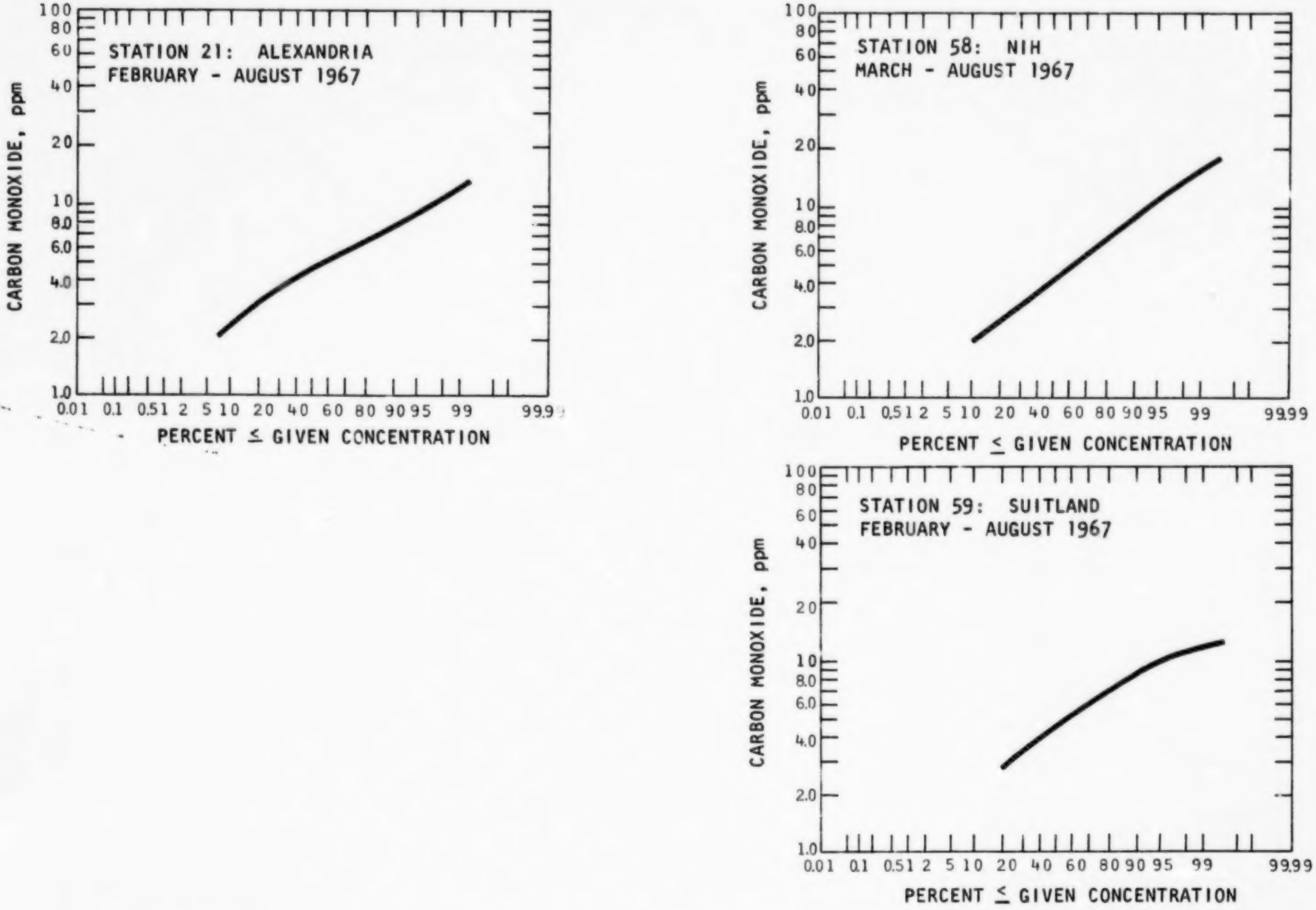

Figure D-10. Hourly average CO cummulative frequency distribution at stations 21, 58, and 59.

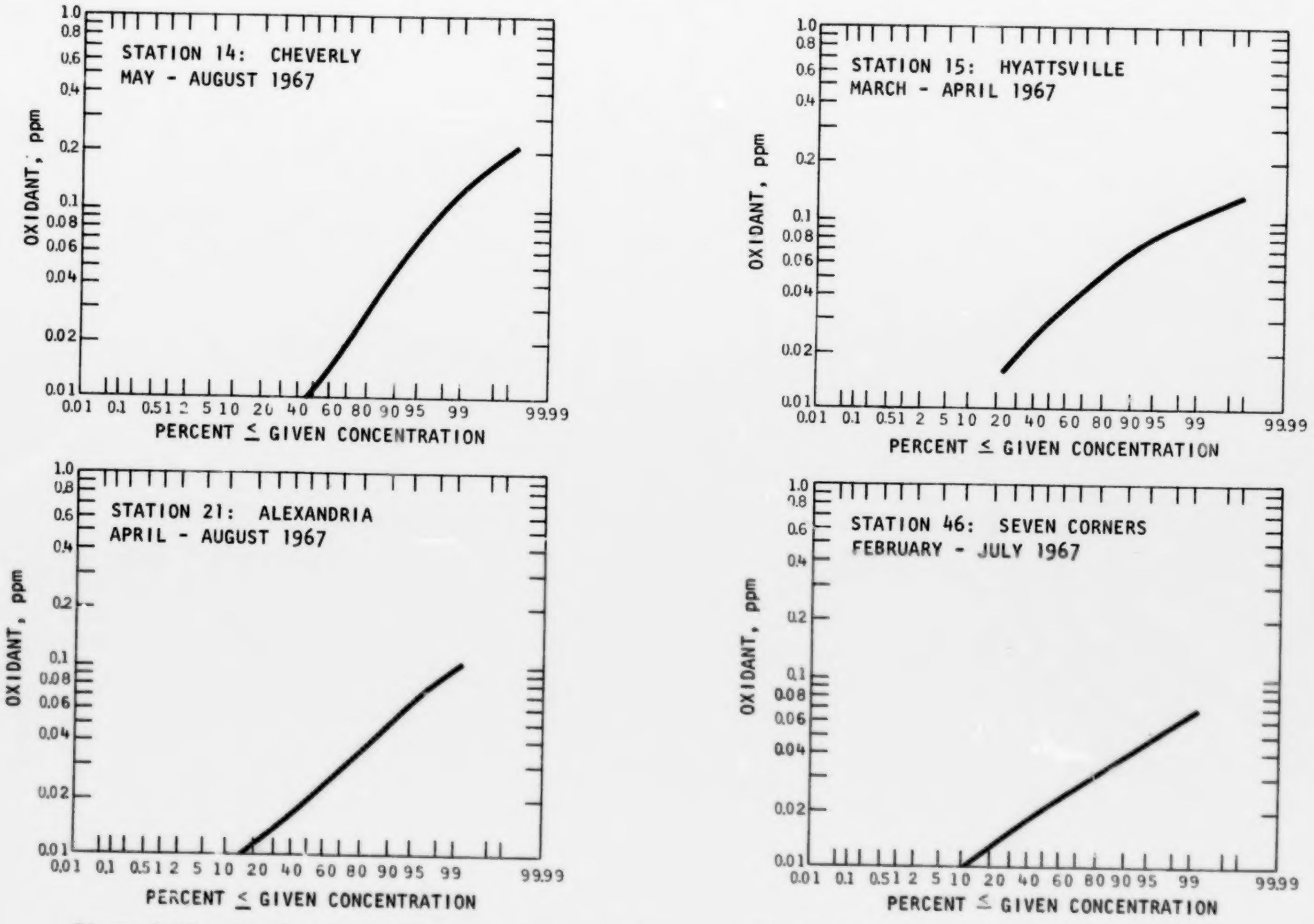

Figure D-11. Hourly average oxidant cummulative frequency distribution at stations 14, 15, 21, and 46.

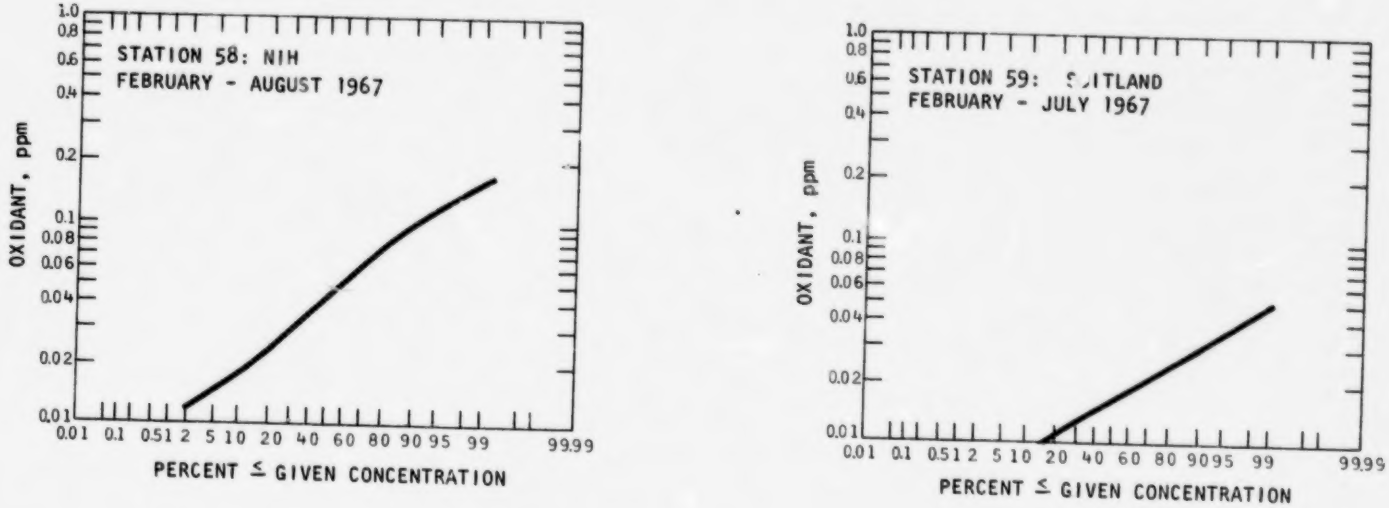

Figure D-12. Hourly average oxidant cummulative frequency distribution at stations 58 and 59.

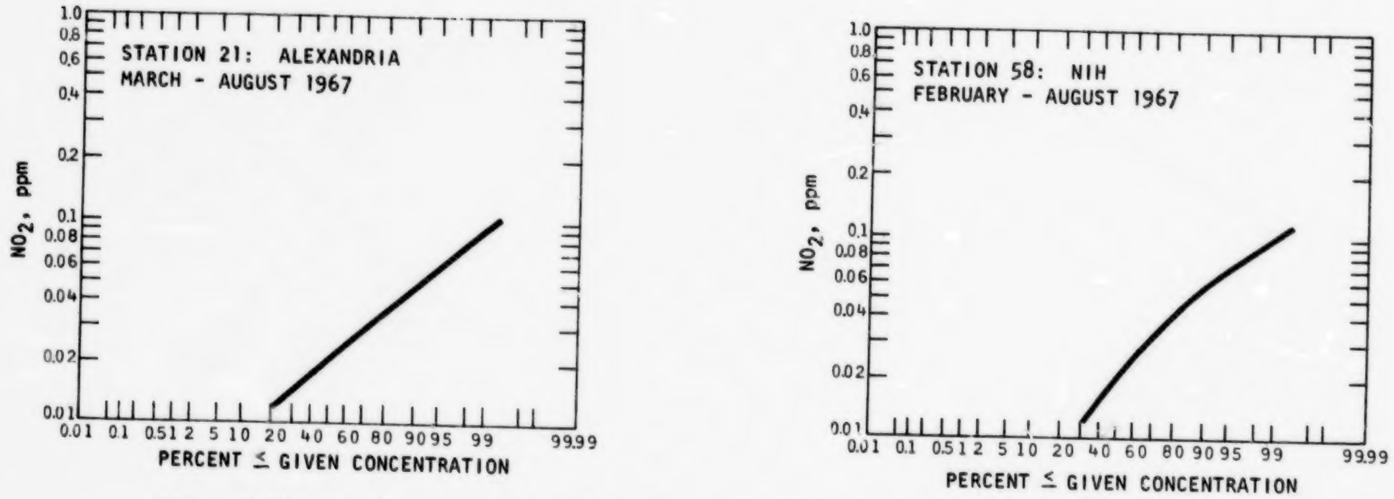

Figure D-13. Hourly average NO_2 cummulative frequency distribution for stations 21 and 58.

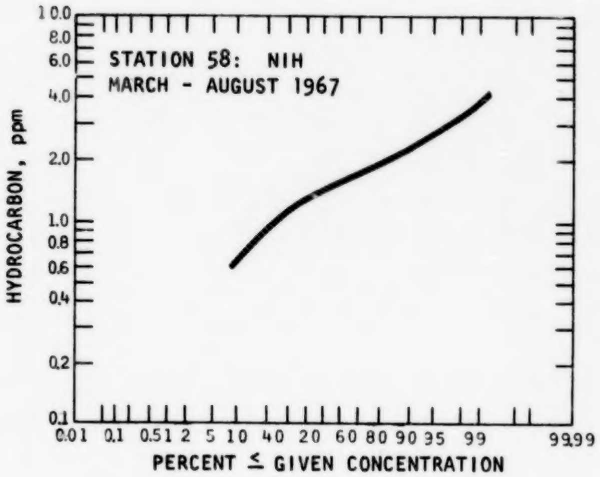

Figure D-14. Hourly average hydrocarbon cummulative frequency distribution for station 58.

Table D-1. EMISSION DENSITIES ON MINIMUM, AVERAGE, AND MAXIMUM SPACE-HEATING DAYS FOR DISTRICT OF COLUMBIA

Zone	Area, mi^2	Sulfur oxides, tons/day-mi^2			Nitrogen oxides, tons/day-mi^2			Particulates, tons/day-mi^2			Carbon monoxide, tons/day-mi^2	Hydrocarbons, tons/day-mi^2
		Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Avg.	Avg.
DC-1	0.7	0.2	6.1	8.5	2.1	4.5	7.9	0.3	1.0	1.9	48.3	11.1
DC-2	0.7	0.8	4.5	8.7	1.8	3.5	5.8	0.4	0.9	1.5	33.2	10.8
DC-3	0.8	0.3	2.4	6.6	2.4	3.3	4.7	0.3	0.6	0.8	53.7	12.2
DC-4	0.6	0.5	10.3	24.0	4.9	8.3	12.8	0.7	1.3	2.2	106.9	24.1
DC-5	0.8	0.7	12.8	30.1	4.0	4.8	5.9	0.5	1.3	2.3	87.9	19.9
DC-6	1.1	0.9	2.2	14.5	2.4	4.5	7.4	0.4	1.0	1.9	48.1	11.2
DC-7	1.0	0.5	4.7	10.6	2.6	3.8	5.8	0.4	0.6	1.0	63.0	14.2
DC-8	1.4	1.0	5.4	11.6	1.1	2.8	5.1	0.2	0.8	1.3	21.4	5.1
DC-9	3.5	0.3	4.5	10.5	0.8	2.2	4.3	0.3	0.6	1.0	16.1	3.7
DC-10	2.0	0.1	4.5	10.8	1.0	2.0	3.6	0.2	0.4	0.7	19.8	4.7
DC-11	7.0	6.1	5.8	7.5	3.7	2.5	3.0	2.2	2.1	2.2	16.0	5.3
DC-12	3.3	0.1	1.2	2.8	0.3	0.8	1.4	0.1	0.2	0.3	5.0	1.3
DC-13	5.6	Neg.	1.0	2.3	0.4	0.7	1.2	0.1	0.1	0.2	8.4	2.0
DC-14	1.1	0.1	3.1	6.6	0.8	2.0	3.8	0.2	0.5	0.9	14.5	3.6
DC-15	1.4	25.9	22.3	37.3	8.4	8.6	14.6	2.6	3.1	4.5	19.9	4.9
DC-16	6.4	0.1	2.7	6.3	0.3	0.9	1.8	0.1	0.2	0.5	6.8	1.6
DC-17	2.4	0.2	10.3	24.6	1.0	3.5	7.0	0.1	1.1	2.4	22.4	5.1
DC-18	5.0	0.1	0.8	1.8	0.4	0.6	1.0	0.1	0.1	0.2	7.2	1.7
DC-19	5.6	0.4	2.3	5.0	0.5	1.0	1.6	0.1	0.2	0.3	9.0	2.1
DC-20	1.8	0.2	1.5	3.2	0.6	1.2	2.1	0.1	0.3	0.6	11.8	2.9
DC-21	5.2	0.1	1.3	3.0	0.4	0.7	1.2	0.1	0.1	0.2	8.0	1.9
DC-22	4.0	Neg.	1.8	4.1	0.6	1.1	1.7	0.4	0.5	0.6	10.3	2.5

Table D-2. EMISSION DENSITIES ON MINIMUM, AVERAGE, AND MAXIMUM SPACE-HEATING DAYS FOR MONTGOMERY AND PRINCE GEORGES COUNTIES

Zone	Area, mi^2	Sulfur oxides, tons/day-mi^2			Nitrogen oxides, tons/day-mi^2			Particulates, tons/day-mi^2			Carbon monoxide, tons/day-mi^2	Hydrocarbons, tons/day-mi^2
		Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Avg.	Avg.
M-1	169.2	1.0	1.0	1.0	0.2	0.2	0.3	0.1	0.1	0.1	0.2	0.1
M-2	119.8	Neg.	Neg.	0.1	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	0.3	0.1
M-3	25.4	Neg.	0.1	0.2	0.1	0.1	0.1	Neg.	Neg.	Neg.	1.3	0.3
M-4	27.0	0.1	0.2	0.4	0.2	0.3	0.3	0.1	0.1	0.1	4.7	1.1
M-5	100.3	Neg.	Neg.	Neg.	Neg.	0.1	0.1	Neg.	Neg.	Neg.	1.0	0.3
M-6	10.5	0.1	0.3	0.6	0.2	0.3	0.4	Neg.	0.1	0.1	3.7	0.9
M-7	11.7	0.1	0.1	1.3	0.3	0.6	1.1	0.1	0.1	0.2	5.7	1.4
M-8	8.3	0.1	0.3	0.7	0.2	0.4	0.6	Neg.	0.1	0.1	4.7	1.1
M-9	6.6	0.2	0.8	1.8	0.5	0.9	1.4	0.1	0.2	0.3	10.0	2.3
M-10	7.7	0.1	0.9	2.0	0.3	0.5	0.8	0.1	0.1	0.2	7.2	1.7
PG-1	69.2	3.0	2.0	1.6	0.8	0.5	0.4	0.1	0.1	0.1	0.3	0.1
PG-2	126.2	Neg.	0.1	0.1	Neg.	0.1	0.1	Neg.	Neg.	Neg.	0.5	0.2
PG-3	101.3	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	0.5	0.1
PG-4	78.6	Neg.	0.2	0.3	Neg.	0.1	0.1	Neg.	Neg.	0.1	0.9	0.2
PG-5	20.0	Neg.	0.1	0.3	0.2	0.2	0.3	Neg.	Neg.	0.1	4.3	1.1
PG-6	0.7	0.2	1.9	4.3	0.4	1.1	2.1	0.1	0.2	0.5	8.3	2.1
PG-7	25.9	Neg.	0.3	0.6	0.2	0.3	0.4	Neg.	Neg.	0.1	3.8	0.9
PG-8	3.0	0.2	0.7	1.4	0.3	0.6	0.9	0.1	0.2	0.3	5.2	1.3
PG-9	28.4	Neg.	0.1	0.2	0.1	0.2	0.2	0.1	0.1	0.1	3.1	0.8
PG-10	11.0	0.1	0.5	1.1	0.3	0.5	0.6	0.2	0.2	0.2	6.6	1.6
PG-11	5.8	0.2	0.7	1.4	0.5	0.7	1.0	0.1	0.2	0.2	10.0	2.4
PG-12	6.0	0.2	0.9	1.9	0.4	0.7	1.2	0.1	0.2	0.3	6.5	1.7
PG-13	11.7	0.1	0.6	1.5	0.2	0.4	0.7	Neg.	0.4	0.7	3.6	0.9

Table D-3. EMISSION DENSITIES ON MINIMUM, AVERAGE, AND MAXIMUM SPACE-HEATING DAYS FOR ARLINGTON, FAIRFAX, LOUDOUN, AND PRINCE WILLIAM COUNTIES

Zone	Area, mi^2	Sulfur oxides, tons/day-mi^2			Nitrogen oxides, tons/day-mi^2			Particulates, tons/day-mi^2			Carbon monoxide, tons/day-mi^2	Hydrocarbons, tons/day-mi^2
		Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Avg.	Avg.
A-1	9.8	Neg.	0.4	0.8	0.2	0.3	0.5	Neg.	0.1	0.2	4.2	1.0
A-2	4.4	0.3	2.0	4.4	0.6	1.2	2.0	0.1	0.3	0.4	11.8	2.8
A-3	7.5	0.3	1.7	3.5	0.5	0.9	1.4	0.3	0.3	0.4	28.9	2.5
A-4	4.1	0.1	2.1	4.8	1.4	2.3	3.7	0.3	0.6	1.1	27.5	6.9
F-1	185.1	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	0.5	0.1
F-2	84.2	Neg.	Neg.	0.1	Neg.	0.1	0.1	Neg.	Neg.	0.1	1.0	0.2
F-3	14.9	Neg.	0.2	0.5	0.1	0.2	0.3	Neg.	Neg.	0.1	2.2	0.6
F-4	21.1	Neg.	0.1	0.2	0.1	0.2	0.2	Neg.	Neg.	Neg.	2.2	0.5
F-5	23.2	0.1	0.3	0.7	0.2	0.3	0.4	0.1	0.1	0.1	3.8	1.0
F-6	63.0	Neg.	0.2	0.4	0.1	0.2	0.3	Neg.	0.1	0.1	1.5	0.4
L-1	64.0	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	0.2	Neg.
L-2	67.0	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	0.1	Neg.
L-3	72.0	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	0.1	Neg.
L-4	80.5	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	0.2	Neg.
L-5	107.0	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	0.1	Neg.
L-6	128.0	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	0.1	Neg.
PW-1	56.0	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	0.3	0.1
PW-2	71.0	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	0.4	0.1
PW-3	55.6	0.8	0.8	0.8	0.4	0.4	0.5	0.1	0.1	0.1	0.3	0.1
PW-4	0.0	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	0.4	0.1
PW-5	67.0	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	0.5	0.1
PW-6	48.0	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	0.2	0.1

Table D-4. EMISSION DENSITIES ON MINIMUM, AVERAGE, AND MAXIMUM SPACE-HEATING DAYS FOR CITIES OF ALEXANDRIA, FAIRFAX, AND FALLS CHURCH

Zone	Area, mi^2	Sulfur oxides, tons/day-mi^2			Nitrogen oxides, tons/day-mi^2			Particulates, tons/day-mi^2			Carbon monoxide, tons/day-mi^2	Hydrocarbons, tons/day-mi^2
		Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Avg.	Avg.
AL-1	9.0	0.2	1.0	2.1	0.4	0.7	1.1	0.3	0.3	0.5	7.6	1.9
AL-2	1.5	0.3	2.2	4.9	1.6	2.4	3.5	0.3	0.5	0.7	36.8	8.3
AL-3	5.2	11.5	9.9	11.1	6.1	5.2	5.7	0.5	0.5	0.6	12.7	2.9
FAX-1	2.6	0.1	0.5	0.9	1.1	1.4	1.7	0.2	0.3	0.4	26.6	6.2
FC-1	2.0	0.1	0.2	0.9	0.6	0.8	1.2	0.1	0.2	0.3	13.5	3.3

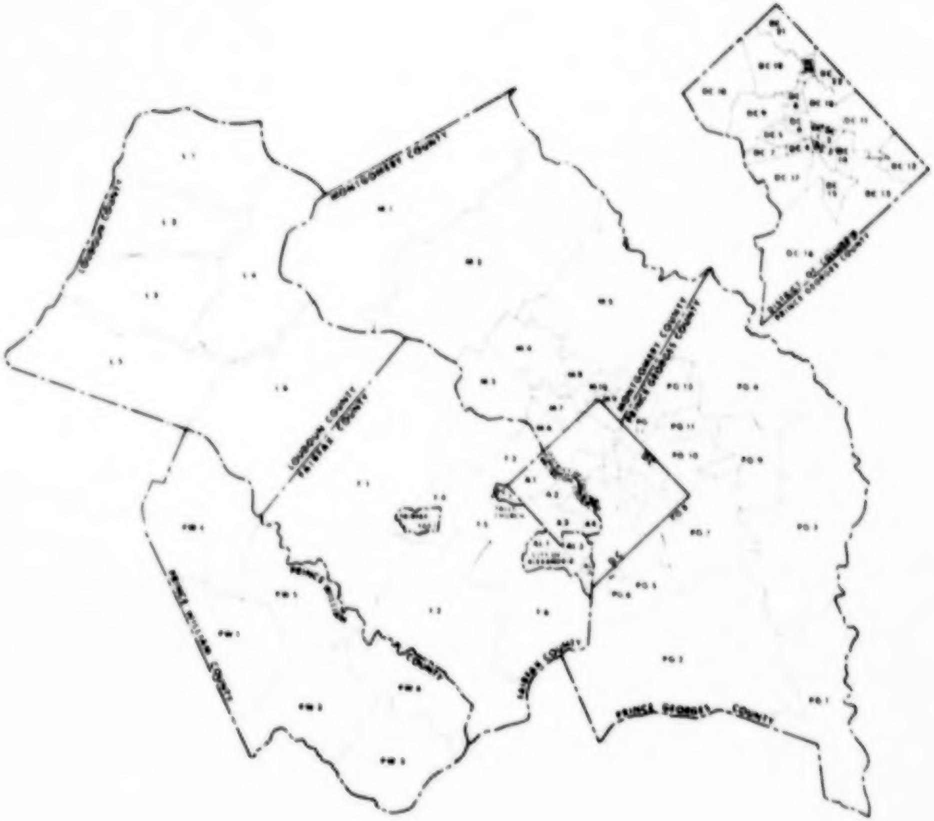
LOUDOUN COUNTY
MONTGOMERY COUNTY
LOUDOUN COUNTY
FAIRFAX COUNTY
MONTGOMERY COUNTY
PRINCE GEORGES COUNTY
DISTRICT OF COLUMBIA
PRINCE GEORGES COUNTY
PRINCE WILLIAM
FAIRFAX COUNTY
PRINCE WILLIAM COUNTY
FAIRFAX COUNTY
PRINCE GEORGES COUNTY

Figure D-15. Emission inventory zones.